A SYSTEMS-BASED INQUIRY INTO PRO-ENVIRONMENTAL BEHAVIOR AND BEHAVIOR CHANGE ACROSS THE PRODUCT LIFECYCLE

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ABSTRACT

The broad topic of this doctoral dissertation is behavior and behavior change related to environmental sustainability and health, with a focus on the role of design and the physical environment. Two studies consider behavior at two different stages in a product's lifecycle: the use phase and a product's end-of-life (product or resource recovery). A third study, with an emphasis on behavior in context, explores pro-environmental behavior in early adulthood.

First, *Creating a New Behavior to Address a New Problem: The Case of Safe Drug Disposal* (Chapter 2) addresses improper disposal or stockpiling of unused, expired, or otherwise unwanted medication and safe disposal behavior, such as returning unwanted medications through a pharmaceutical take-back program. A three-part study, including a cross-sectional survey of drug take-back event participants, a cross-sectional survey of a random sample of New York State residents, and an experimental survey, explored disposal behavior and perceptions of various disposal methods. Findings provide insight into important factors influencing out-of-home disposal behavior, including convenience of and familiarity with disposal locations.

The second study, *Lab Fume Hood Closure: A Behavior Change Experiment* (Chapter 3), looks at behavior associated with the use of an energy-intensive piece of laboratory safety equipment. The study included an experiment to test whether the addition of a closure signifier (a sticker) and the provision of comparative feedback would decrease the number of times fume hoods were left. Findings suggest there are opportunities to improve the design of fume hoods to

indicate proper closure behavior, as well as opportunities to use automated building data to provide laboratory workers with feedback to promote energy conservation.

Finally, *Development of the Environmental Behavior Scale for Young Adults (EBS-YA)* (Chapter 4) describes the process for creating a new, valid and reliable pro-environmental behavior scale relevant to young adults who have limited control over their environment and do not own a home. The resulting 32-item scale, which poses questions for specific physical contexts, can be used to evaluate interventions (with pre and post measures) and can be used to facilitate longitudinal research that assesses pro-environmental behavior over the lifespan.

BIOGRAPHICAL SKETCH

Kristin Aldred Cheek is an environmental psychologist who has applied her interests in design, nature, and people in a number of settings to contribute to a sustainable, healthy future for all. After graduating from Wesleyan University with a degree in psychology, she joined an environmental consulting firm where she conducted energy conservation studies and participated in some of the nation's first "corporate greening" projects. She continued her education at Oregon State University, where she earned a master's of science degree in Forest Resources, with an emphasis on the social sciences. While in Oregon and later at the University of Montana, she investigated the relationship between natural resource policy, economic impacts, and community capacity. She also focused on public participation in and collaboration on natural resource management issues. Her continued interest in the relationship between people and environments led her to a stakeholder relations role at an environmental remediation firm, where she facilitated interactions among corporations, governments, and local citizens in places impacted by contamination from a closed oil refinery, a fueling station, and a train derailment. She stepped back from her career to focus on family for a time, and then ramped up from part-time communications and sustainability work at schools to help to launch a startup focused on accelerating emerging innovations. While at the startup, she began to see products and strategies using design to alter behavior and decided to pursue graduate work that blended her interests in behavioral science, design, and business. Design and Environmental Analysis at Cornell University is an interdisciplinary program that uses a systems model to understand human-environment relationships and recognizes the important connections between environmental and human health. Kristin is currently applying her knowledge of sustainability, behavior, and business in the field of product stewardship and extended producer responsibility.

In memory of dad, whose boat rides and walks in the mountains

forever shaped my view of the world and the important things in it.

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CHAPTER 1

INTRODUCTION

Continued environmental degradation threatens both the health of natural systems and human health. In terms of overall resource use and deleterious effects on our natural environment, we have passed the point at which the natural environment can effectively process wastes being generated by human activity (United Nations, 2012). As pressures from population growth and expanding development continue, societies face numerous issues ranging from groundwater pollution to soil contamination, resource shortages, species loss, the accumulation of solid waste, and the disruption of basic natural cycles on which human life depends (Steffen, Grinevald, Crutzen, & McNeill, 2011; U.S. Environmental Protection Agency, 2014). While environmental problems were once treated in relative isolation from other human problems, it is also now widely accepted that environmental problems are tightly interwoven with human health (Nisbet & Gick, 2008; Srinivasan, O'Fallon, & Dearry, 2003; Wells, Evans, & Yang, 2010). Air pollution alone, which is implicated in heart disease, stroke, respiratory illnesses, and cancer, is responsible for one in eight deaths worldwide (World Health Organization, 2014).

Technological change promises significant opportunities to mitigate environmental impacts. Emerging innovations can achieve more efficient and less resource-intensive housing, transportation systems, and products. However, there is also opportunity to make a difference, in some cases more immediately, through individual behavior change (Lehman & Geller, 2005; Steg & Vlek, 2009), particularly in the United States where individual activity accounts for an outsized-share of global environmental impacts (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009) and individual lifestyle choices account for 85 percent of energy use (Bin & Dowlatabadi, 2005). To minimize the environmental and health impacts of current technologies, as well as to ensure that new technologies are adopted with maximum effect, it is essential that we better understand the relationship between human behavior and our environment, including how we interact with products and the built environment, the resource use that stems from those interactions, and the potential to recover resources and manage waste from products that have reached the end of their useful lives.

Environmental Psychology and Behavior

The field of environmental psychology (also referred to as human-environment relations) is well suited for inquiry into the relationship between human behavior and our environment. Environmental psychology is an interdisciplinary field oriented toward applications, problem solving, and the study of behavior in everyday settings (Gifford, 2014). Environmental psychologists draw from theories across disciplines to develop holistic models of human behavior.

One of the most important examples of interdisciplinary and holistic thinking in environmental psychology is the bio-ecological model, which has been adapted from the field of human development (Bronfenbrenner & Morris, 1998) and has been applied effectively to public health issues (Booth et al., 2001; McLeroy, Bibeau, Steckler, & Glanz, 1988). The bio-ecological model provides a useful framework for understanding complex systems and multiple factors that influence human behavior. As illustrated in Figure 1, the individual is at the center of a series of nested sub-systems. The interrelated subsystems range in scale from the microsystem (e.g., home, school, neighborhood), to the exosystem (e.g, media, industry), and macrosystem (e.g., culture, policy). Mesosystems refer to interactions among microsystems. The chronosystem (not shown) accounts for influences over time or the influence of events occurring at a specific time. In the center, the model accounts for individual characteristics, including personal dispositions, bioecological resources (e.g., ability, knowledge, experience, skills), values, and attitudes.

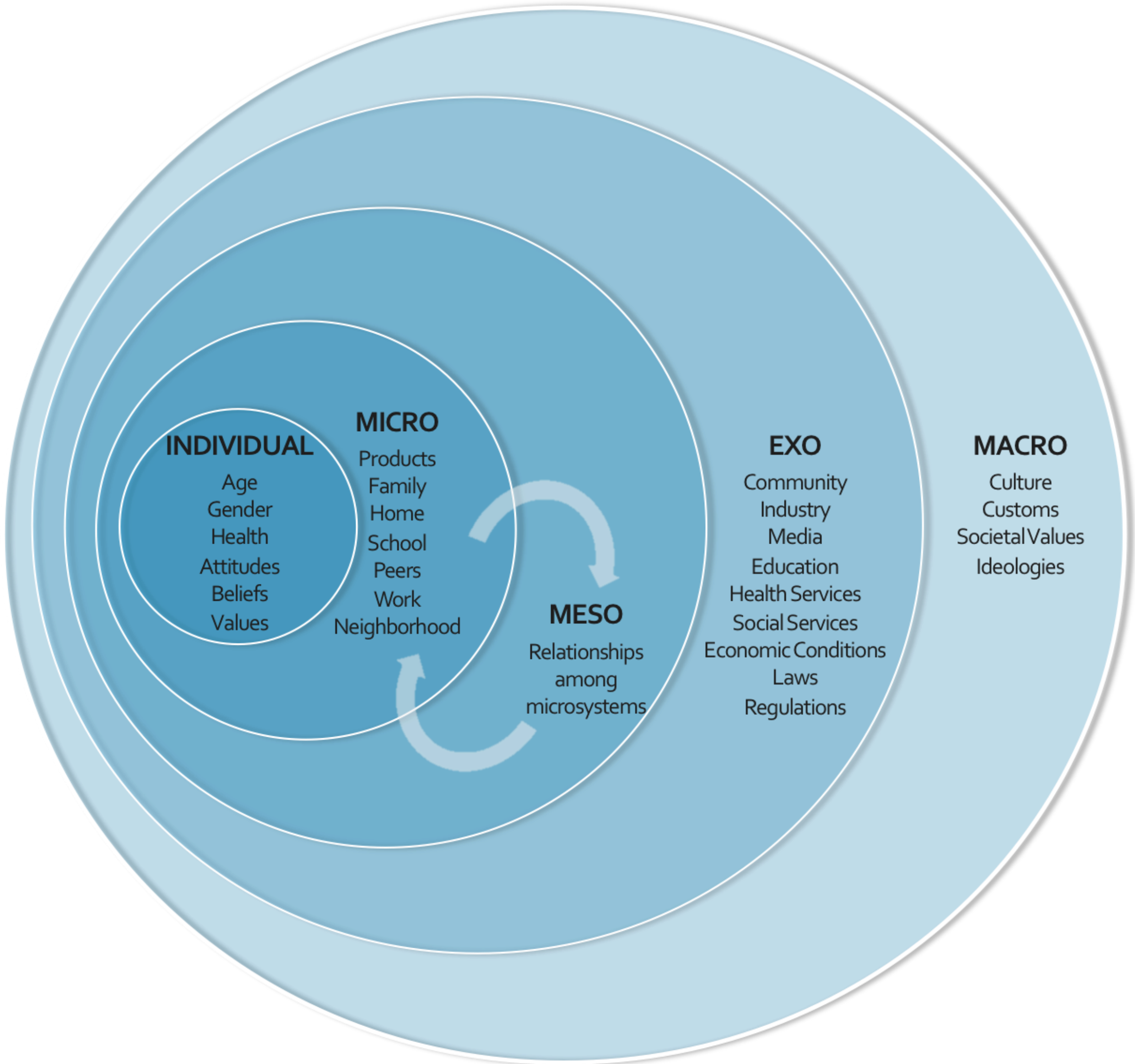

Figure 1: The Bio-Ecological Model

The field of public health has shifted from a focus on individuals, with primarily educational interventions targeting individual beliefs, attitudes, and behaviors, to a systems or ecological focus with multi-level interventions that target environmental or contextual factors, most notably the physical environment and policy to impact behavior on the community level (French, Story, & Jeffery, 2001; McLeroy et al., 1988; Razani & Tester, 2010; Sallis, 1998; Stokols, 1992b; Story, Kaphingst, Robinson-O'Brien, & Glanz, 2008; Wells, Ashdown, Davies, Cowett, & Yang, 2007). Within the field of public health, there is a recognition that overcoming poor health behaviors often requires more than information provision and often-associated changes in attitudes or intentions, and that the physical environment plays an crucial role in supporting healthy behaviors (Nisbet & Gick, 2008; Stokols, 1992a). Contemporary research and interventions related to physical activity, healthy eating, obesity, and chronic health conditions consider such factors as the availability of safe walking routes, access and availability of fresh foods, access to public transportation, and the varied influences of home, school, work, and neighborhood environments.

Theories and knowledge regarding health behavior change, including an ecological or systems approach, can be applied to environmentally sustainable behaviors (Nisbet & Gick, 2008). In fact, many behaviors, such as eating a plant-based diet or walking rather than driving a car, can be characterized as pro-environmental, as well as healthy. The ecological model can serve as a valuable framework for investigating and understanding a range of influences on pro-environmental (or environmentally sustainable) behavior at different scales and in different contexts. Although environmental or contextual factors have been given significant attention recently in health behavior research, such factors have been given relatively less consideration in pro-environmental behavior research.

Environmental Sustainability and Individual Behavior

The problem of environmental impacts stemming from individual behavior has been largely framed in terms of altruism, morality, and often sacrifice, and the body of research on individual pro-environmental behavior has focused on awareness, knowledge, beliefs, values, and attitudes regarding environmental problems (De Young, 2000; Gardner & Stern, 2002; Kaplan, 2000). Persuasion, information provision, feedback, and inducing norms have each proven somewhat effective in increasing pro-environmental behavior, with the most effective interventions typically using some combination of strategies (Gardner & Stern, 2002; Schultz, 2014; Steg & Vlek, 2009; Stern, 2000). The scale and continued proliferation of environmental problems and consequent impacts on human health, along with a persistent gap between attitudes and behaviors, as well as between intentions and behaviors (Kollmuss & Agyeman, 2002; Kurz, 2000; Winter & Koger, 2004), suggests the need for an expansion in approaches to bringing about pro-environmental behavior.

The field of behavioral economics largely focuses on decisions that involve a choice, specifically where people's stated or inferred best interests and their actual choices do not line up (Akerlof & Kennedy, n.d.; Thaler & Sunstein, 2003). Behavioral economics interventions employ “choice architecture” to alter the decision context while preserving a person's ability to choose (Akerlof & Kennedy, n.d.; Sunstein & Reisch, 2014; Thaler & Sunstein, 2003). Two important concepts are people's use of heuristics, or rules of thumb, when making decisions, and the tendency for people to favor the status quo (Reisch & Sunstein, 2014). Behavioral economics essentially looks to take advantage of our natural ways of thinking – including systematic errors and our use of shortcuts – to improve individual and sometimes collective wellbeing. While the foundation of behavioral economics is at the level of the individual, interventions can take place at different levels (e.g., adjusting choices within a microscale or changing policy at the macroscale).

Within the field of behavioral economics, environmental sustainability is typically approached in terms of whether consumers choose environmentally friendly products (e.g., efficient or non-toxic products) (Campbell-Arvai, Arvai, & Kalof, 2014). In the case of environmental sustainability, the most common type of behavioral economics intervention is the use of a default option (an option that kicks in if an individual does not make a choice) (Croson & Treich, 2014; Reisch & Sunstein, 2014; Sunstein & Reisch, 2014). Because of the status quo bias, people have a tendency to stick with the default option. People are also sensitive to losses and may perceive movement away from the default as a loss. For example, in two real-world settings, most utility customers offered electricity from green (renewable) sources as the default kept it (Pichert & Katsikopoulos, 2008). In lab experiments involving electricity choice, participants also were more likely to stick with the default, even if it was more expensive.

Sunstein and Reisch (2014) suggest small changes using default options could potentially have a greater impact on environmental quality than economic incentives, education, or moral appeals.

Note that Sunstein and Reisch (2014) make a distinction between physical design interventions that make an option more accessible or salient, and choice architecture. They refer to environmental design changes to support sustainable behavior, such as visible and attractive bicycle lanes, as a "close cousin" of default rules. There is a distinction between environmental design and choice architecture, though many of the same underlying psychological principles are at work.

The physical context in which behaviors are carried out has received relatively little attention in pro-environmental behavior research than many other factors, but there has been a small amount of research using design or physical alterations in the environment to promote pro-environment behaviors. Environmental or design alterations can create opportunities for sustainable behaviors to become more salient or convenient (Lehman & Geller, 2005). For example, one intervention that involved the use of specialized recycling lids (with round or rectangular openings for bottles/cans or paper) resulted in a 34 percent increase in recycling and a 95 percent reduction in the amount of contaminants entering the recycling stream (Duffy & Verges, 2009). The lids increased recycling compliance by providing "perceptual affordances" beyond labels on the containers. One reason the intervention may have been effective was that the physical alteration of the lids reduced people's cognitive demands (Duffy & Verges, 2009). In other words, recycling was simpler, almost automated. Reusable bag use in Canada become more widespread not through information provision or persuasion, but when a major grocery store chain took a new approach to the bags themselves and their placement (Nisbet & Gick, 2008). When the store began selling a "stylish" design with easy access at the checkout, behavior changed.

Within the design field, there is interest in proactively using design to facilitate pro-environmental behavior ("Designing-in," 2008). Unlike other sustainable design approaches that focus on the efficiency, toxicity, material content, reusability, or recyclability of products, "design for sustainable behavior" focuses on changing how products are used while they are in customers' hands, thereby changing resource consumption during the use phase of products ("'Designing-in' sustainable behavior," 2008; Lilley, 2009; Lockton, Harrison, & Stanton, 2008; Tang & Bhamra, 2009). Designers aim to change behavior through two general means: by providing feedback that makes consumption more tangible or by steering behavior – by making a preferred behavior easier through affordances, introducing obstacles, or providing guidance.

Behavior and the Product Lifecycle

Once a product has been purchased or a building has been built, individual behavior[1] has substantial implications for environmental impacts during two phases of a product's lifecycle: the use phase (e.g., from water and energy use associated with washing clothing) and a product's end of life (e.g., return or disposal of a product) (Bin & Dowlatabadi, 2005) (see Figure 2).

A large portion of resource use associated with products and the built environment occurs during the "use phase" (Sorrentino, Woelbert, & Sala, 2016). Changing the way people use buildings, products, cars, equipment, and other aspects of the built environment, then, can have a large impact on resource use, including energy and water consumption. A number of consumer product companies have conducted lifecycle assessments of their products and discovered that a large percentage of the resource use associated with their products occurs when a product is in their consumers' hands, and then launched efforts to change consumer behavior. For example, Levi's led a campaign asking its customers to wash jeans less often to save water and energy (Bergh, 2014), and both Procter and Gamble and Unilever have encouraged customers to wash laundry in cold water to save energy (Rowley, 2011). Reducing consumption during the use phase presents a potentially cost-effective way for companies to reduce their overall environmental footprint.

[1] Individual behavior refers in this research to consumers or users. Individual designers' choices regarding materials and overall product design have similarly important implications for environmental impacts, but are not addressed here.

Figure 2: Product Lifecycle

Individual decisions made at the end of a product's life can also have important implications for the natural environment, and companies are under increasing pressure to share responsibility for the entire lifecycle of their products through disposal or reuse (U.S. Environmental Protection Agency, 2012). Extended producer responsibility, along with increased recognition of the value of materials embedded in spent products, has led companies to look for ways to improve resource recovery. Johnson & Johnson and Coca Cola, for example, both commissioned studies on home recycling practices as a way to discover how to improve the recycling rates for their products' packaging (Boulay, Barr, & Shaw, 2013; Johnson & Johnson, 2013). The pharmaceutical industry is increasingly being required to contributed to the cost of collecting and safely disposing of leftover drugs (see for example, The New York State Senate, 2018). Closing the loop on consumption, such that resources are recovered for continued use or at least for low-impact disposal, can have a significant impact and human and environmental health.

Dissertation Overview

This dissertation brings a systems-based environmental psychology perspective and increased consideration for the physical environment to a topic that has been studied largely through the lens of social and personality psychology. A systems view facilitates the study of behavior that focuses on specific factors, including those at the individual level, but also acknowledges the role of policy, the physical environment, and other factors. The dissertation studies also look to health psychology and cognitive psychology, including knowledge of routine and habitual behavior, for insights that will help improve the effectiveness of pro-environmental behavior change efforts. The overarching purpose of the research is to investigate pro-environmental behaviors during the use phase or end-of-life phase of a product's lifecycle and in context.

The first study, "*Creating a New Behavior to Address a New Problem: The Case of Safe Drug Disposal*," (Chapter 2) addresses the serious and growing problem of leftover medication storage and disposal. Research questions regarding how people dispose of unwanted medications, perceptions of various disposal methods, and the characteristics of people who participate in pharmaceutical take-back programs are explored through a survey distributed at a take-back event, a random population survey of New York State residents, and an experimental survey. The study contributes to our understanding of individual behavior at the end of a product's life and the role of environmental supports and barriers in that behavior. The second study, "*Lab Fume Hood Closure: A Behavior Change Experiment*," (Chapter 3) tests a behavior change intervention that uses an environmental signifier (a cue) and feedback. The study contributes to our understanding of use-phase behavior, particularly repeated or habitual behavior associated with the use of a product. The third study, "*Development of the*

Environmental Behavior Scale for Young Adults (EBS-YA)" describes the development of a valid and reliable scale to measure young adults' pro-environmental behavior. The scale gives consideration to the context in which behaviors occur and fills a gap in the literature, which to date focused primarily on older adults and younger children.

Together the three studies represent one step toward a more ecological approach to pro-environmental behavior, similar to the approach being taken in public health research. Findings will be of interest to individuals trying to change their behavior, designers configuring environments and developing products to support desired behaviors, business interested in reducing the lifecycle impacts of their products, and policymakers interested in alleviating environmental health problems or mitigating environmental impacts through behavior change.

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CHAPTER 2

CREATING A NEW BEHAVIOR TO ADDRESS A NEW PROBLEM: THE CASE OF SAFE DRUG DISPOSAL

ABSTRACT

Improper disposal or stockpiling of unused, expired, or otherwise unwanted medication is a serious public health and environmental health issue. Medications disposed through wastewater (i.e., flushing or washing down a drain) or in the trash can enter waterways and eventually drinking water supplies, while leftover medications stored in the home can be diverted for nonmedical use and abuse. Take-back programs offer individuals a way to safely dispose of unwanted medications, yet little is known about their effectiveness, or more generally about factors that influence drug disposal behavior. Focusing on environments and behavior, three studies explored several research questions regarding how people dispose of unwanted medications, perceptions of various disposal methods, and the characteristics of people who participate in pharmaceutical take-back programs. Findings show that drug disposal is a common behavior, with upwards of 80 percent of people having disposed of a drug at some time. A majority of people dispose of unwanted medications at home through the trash or flushing. Findings suggest that for out-of-home disposal, people prefer familiar places, such as pharmacies and public waste facilities, over police stations. Findings also indicate that older adults and people who are concerned about the environmental impacts of disposed drugs are more likely to use out-of-home disposal methods, such as a drug take-back event. However, convenience is the overriding factor for most people when choosing a disposal method, which suggests that efforts to provide more supportive environments or reduce barriers might alter drug disposal behavior.

INTRODUCTION

The disposal or stockpiling of unused, unwanted, or expired pharmaceuticals presents an environmental problem impacting water quality and a public health problem linked to the opioid epidemic. One emerging solution is drug take-back, or programs that facilitate the return of unwanted medications from households to official drop-off sites for safe disposal (typically incineration). Drug take-back is a relatively new disposal method. By developing a better understanding of individuals' current disposal practices and factors that influence drug disposal behavior, research can contribute to ongoing efforts to increase drug take-back activity, to divert medications from waterways and wastewater streams, and to ensure safe drug disposal.

Drugs in Water

The problem of drugs in the environment, particularly in drinking water, came to the fore in the United States after the U.S. Geological Survey (USGS) published a report on water contamination (Barnes et al., 2008). In 2000 and 2001, the USGS collected and tested samples from 25 groundwater and 49 surface water locations that supply drinking water in 43 states. The testing was done to create a baseline measurement for the presence of 100 pharmaceuticals and other contaminants. Results showed traces of over-the-counter and prescription medications present in the drinking water supplies of an estimated 41 million Americans (Associated Press, 2008). Pharmaceuticals detected included antibiotics, anti-seizure drugs, hormones, painkillers, and heart medications. The cumulative effects of these substances in waterways on humans is largely unknown, although there is considerable documentation on specific drugs' adverse effects on wildlife, including fish, amphibians, and birds, as well as the growing threat of antibiotic resistance (Shah, 2010).

Individual, at-home disposal of unwanted medications is one source of water contamination (Bound, Kitsou, & Voulvoulis, 2006). The most common forms of disposing of expired and leftover medications in the U.S. are flushing them down the toilet, washing them down the sink, and putting them in the trash (Glassmeyer et al., 2009; Kotchen, Kallaos, Wheeler, Wong, & Zahller, 2009; Kozak, Melton, Gernant, & Snyder, 2016; Law et al., 2015; Lystlund, Stevens, Planas, & Marcy, 2014; Ma, Batz, Juarez, & Ladao, 2014; Musson, Townsend, Seaburg, & Mousa, 2007; Stoddard et al., 2017; Wieczorkiewicz, Kassmali, & Danziger, 2013). Most wastewater treatment systems are not designed to remove pharmaceuticals before releasing effluent to waterways, so flushing or washing medications down drains results in water pollution (U.S. Environmental Protection Agency, 2010). Disposing medications in a solid waste stream can have the same result: pharmaceuticals have been found in landfill leachate (Ramakrishnan et al., 2015), which eventually enters groundwater.

Leftover Drugs, Addiction, and Overdose

At the same time scientists were coming to understand the presence of pharmaceuticals in waterways, opioid addiction was gaining momentum. In 2016, there were 63,632 drug overdose deaths in the United States (Seth, 2018). Two thirds of these deaths (42,249) involved an opioid. The rate of overdose deaths related to synthetic opioids increased 100 percent from 2015 to 2016. The opioid epidemic has grown across age, race, and gender categories throughout the U.S. In 2016, nearly 12 million Americans reported abusing heroin or prescription opioids in the past year (Ahrnsbrak, Bose, Hedden, Lipari, & Eunice, 2017). More than 90 percent of this abuse was of prescription painkillers, including hydrocodone, oxycodone, morphine, and fentanyl products. Approximately two million people were categorized as having an opioid dependence or an opioid use disorder.

Patients filling opioid prescriptions after surgery often find themselves with a reservoir of unused painkillers. Based on a review of studies regarding post-surgery opioid use, 42 to 71 percent of patients who fill opioid prescriptions had unused tablets, most of which were stored in an unlocked cabinet (Bicket et al., 2017). Only four to nine percent planned to dispose of that medication using a drug take-back method. Many people with leftover medications simply store them indefinitely. In a national survey of adults with an opioid prescription, a majority had or expected to have leftover medication, and 61.3 percent would hold on to them for future use (Kennedy-Hendricks et al., 2016). One-fifth admitted to having shared their medication with someone else. More than half of people who have abused prescription painkillers (53%) obtained them through friends or relatives, typically for free (Ahrnsbrak et al., 2017). Small percentages either bought or stole the medications from friends or relatives. Only six percent purchased prescription painkillers from a drug dealer, and less than one percent stole them from a health care provider. The remainder of people abusing prescription painkillers obtained them through one or more doctors.

Overall, the phenomenon of leftover medications is common. Estimates range from roughly one-third to three-quarters of dispensed medications go unused (Law et al., 2015; Stewart et al., 2014). Reasons people do not finish taking medications include side effects, abatement of symptoms, alteration in prescription or dosage, ineffectiveness, and forgetfulness (Law et al., 2015).

Drug Take-Back Programs

Given that so many people who abuse prescription medications obtain them through the homes of people they know, proper medication disposal has been identified as one important strategy for combatting opioid addiction and drug overdose. Proper disposal is also an important method for preventing drug-related environmental contamination (Gray & Hagemeier, 2012). Drug take-back is a safe disposal solution (U.S. Drug Enforcement Agency, n.d.; U.S. Environmental Protection Agency, 2015).

Disposal through pharmaceutical take-back programs is relatively new in the U.S. No comprehensive policy on take-back programs exists; collection efforts vary from state-to-state and county-to-county. Existing permanent pharmaceutical take-back locations include law enforcement offices, healthcare facilities, and drug stores. Some permanent locations are available 24/7, while others are limited to business hours. In contrast, take-back events, such as the annual National Prescription Drug Take-Back Day, started in 2010 by the Drug Enforcement Agency (DEA), are held periodically, typically last one day, and usually take place at a public waste facility or other public facility. A limited number of mail-back programs exist as well.

Although major federal agencies promote take-back as a preferred disposal method, they continue to offer guidance on additional methods. In some cases, an agency might recommend an alternative method (such as disposing of drugs in the trash with an unappealing substance, like cat litter) if no take back program is readily available. In other instances, such as the case with a dangerous painkiller like fentanyl, an agency might recommend disposal via flushing as the safest action in the immediate term (Federal Drug Administration, 2018). Overall, because there are a lot of different entities involved (e.g., government agencies, healthcare organizations, pharmaceutical companies), with differing priorities (e.g., environmental protection, drug abuse prevention, poison prevention, profit and liability management), information presented to the public about drug disposal methods can be contradictory. Messages about what to do with leftover drugs are further complicated by the fact that controlled substances (a class of drugs that includes addictive painkillers) historically have been governed by different rules for handling and disposal. Until recently, only law enforcement agencies were allowed to collect and dispose of controlled substances. Without law enforcement involvement, take-back programs could not accept controlled substances, and old medications had to have intact labels, making participation more complicated for people who might not be aware of what was categorized as a controlled substance, had already removed a label in anticipation of disposal and a desire for privacy, or were concerned about being in possession of a controlled substance.

The Secure and Responsible Drug Disposal Act was designed to make it easier for people to dispose of controlled substances (Secure and Responsible Drug Disposal Act of 2010, 2010). Regulations put in place after the Act was passed allow pharmacies and other entities registered with the DEA to take back medications without law enforcement oversight (Kinrys, Gold, & Nierenberg, 2016). A handful of counties and cities in the U.S. recently adopted laws and ordinances mandating pharmaceutical companies or retail pharmacies pay for consumer take-back programs, which can provide the funding to create permanent take-back locations (Hernandez-Delgado & Davis, 2017). The federal government is also exploring options for more uniform collection (Dellinger, 2011).

Several studies have described take-back program operation and amounts collected. One early program was a mail-based pilot in Maine funded by the Environmental Protection Agency (Ruhoy & Kaye, 2009). Envelopes were available at 150 locations throughout the state, including drug stores, medical offices, community agencies, police departments, and hospices. The envelopes were addressed to the Maine Drug Enforcement Agency (to comply with existing laws regarding controlled substances). Approximately half of participants reported that they would have flushed their medications down the toilet if the take-back program had not been available. Researchers concluded that the program was successful in part because the process was straightforward and user-friendly. However, the program ended due to lack of funding. The largest survey of take-back events is from North Carolina (Fleming et al., 2016). Nearly 1,400 events were held across the state between 2010 and 2014. During that time, people turned in almost 70 million doses of medication.

Take-back programs do collect substantial amounts of drugs, but they likely only capture a small percentage of leftover medications. For example, state officials in Wisconsin estimated that one-third of drugs in the state go unused, and of these only two percent were returned through take-back programs (The University of Wisconsin Extension, 2012). A study in Kentucky found that just 0.3 percent of dispensed controlled substances were recovered through take-back events and boxes (Egan, Gregory, Sparks, & Wolfson, 2016). Overall, relative to the prevalence of leftover medications in U.S. households, participation in drug take-back programs is low.

While research points to a lack of knowledge regarding safe medicine disposal (Wieczorkiewicz et al., 2013), educational efforts have been growing, especially since the onset of national take-back days. Following an awareness campaign for a community take-back event in New Jersey, a survey of residents found 60 percent of the adult population had been exposed to event messages (Yanovitzky, 2016). However, there is some evidence of a gap between knowledge about safe drug disposal and safe disposal action. For example, in an Indiana survey using a convenience sample of pharmacy patients who had leftover medications, 40 percent of participants reported they were aware of a local take-back location, but only 15 percent reported using one (Kozak et al., 2016). Most survey participants reported flushing unwanted medications, throwing the medications in the trash, or storing the medications at home. In Cook County, Illinois, approximately two-thirds of survey respondents agreed that the best disposal method was returning medications to a secure box in a pharmacy or physician's office, and 75 percent stated that flushing was an inappropriate disposal method due to potential environmental impacts (Wieczorkiewicz et al., 2013). However, 31 percent reported flushing, more than half reported using the trash, and only 15 percent reported returning to a pharmacy or doctor's office.

Drug Disposal Behavior and the Physical Environment

The physical environment plays an important role in supporting health behaviors generally (Stokols, 1992a), and likely influences drug disposal behavior as well. Engaging in healthy behaviors, or overcoming unhealthy behaviors, often requires more than awareness or information (Nisbet & Gick, 2008). People face various physical barriers to participating in healthy behaviors, such as lack of public infrastructure. The physical environment, in conjunction with the social environment can also enable health behavior (e.g., passive safety belts in cars support seat belt usage, sidewalks promote walking, availability of recreation facilities encourage physical activity) and can provide health resources (e.g., health care services and community sanitation systems) (Stokols, 1992b).

Research on human decision-making suggests that behavioral interventions designed to fit within people's existing routines and to be convenient (even automatic) will be more successful than programs that require individuals to learn new behaviors or to go out of their way to perform a behavior (Kahneman, 2011; Kaplan & Kaplan, 2008). Disposing of drugs at a take-back location requires more effort than disposing of them at home (Gray, Hagemeier, Brooks, & Alamian, 2015). Where take-back sites are located and how often and when they are available are factors that may affect the ease or difficulty of participation in take-back programs. Research suggests that pharmaceutical drop-off locations draw from a limited geographic area (less than 10 miles) and that willingness to travel tapers off after about four miles (Gray JA & Hagemeier

NE, 2012; Stoddard et al., 2017; Thach, Brown, & Pope, 2013). Research also suggests that drop-offs at well-known stores might be more effective than drop-offs at county health offices, fire departments, or a hazardous waste collection centers (Musson et al., 2007). In one pilot program in Florida that offered several options including local pharmacies, county health offices, a fire department, and a waste collection center, the most disposal activity occurred at a national chain store (Musson et al., 2007). Drug collection boxes located at law enforcement sites in particular are unlikely to be part of most residents' normal routine, and are therefore inconvenient to find, which reduces participation (The University of Wisconsin Extension, 2012).

Drug take-back participation also may be influenced by how the issue of leftover drugs is presented (i.e., as an environmental problem or a drug abuse problem). There is a small amount of evidence that people's choice of disposal method, and in particular, their choice to participate in drug take-back, is influenced by their concern for the environment. In one study of a permanent drop-off site at a pharmacy, participants reported that environmental protection was the most salient reason for disposing method choice (Thach et al., 2013). Unfortunately, it is not clear from most published research what messaging was used for the take-back events studied (see for example Ma et al., 2014; Musson et al., 2007). It would be useful to consider whether presenting the problem in terms of environmental health versus drug abuse might influence people's willingness to expend effort to participate in take-back programs. It is also possible that particular messages resonate with different populations, varying for example, by age or among genders.

Present understanding of an ideal drug take-back program is one that is continuous, conveniently located, free or inexpensive, and simple to use (Glassmeyer et al., 2009; Lystlund et al., 2014). The EPA has advocated for a program that is "available" (Dellinger, 2011). Convenience and availability parameters are not well defined, and little research exists regarding whether or how a program's design influences take-back behavior. More research is needed to understand people's preferences surrounding drug disposal. Such research would help inform the design of effective take-back programs to support safe drug disposal behavior.

Current Research

The current research project consists of three studies intended to provide further insights into drug disposal and take-back behavior. The main aim of *Study 1* was to obtain an accurate estimate of disposal methods being used in a general population. Study 1 consisted of two questions on the Empire State Poll, which is a random population survey of New York State residents. The research questions for Study 1 were:

RQ1. How do people dispose of unwanted medications?

RQ2. Are age or gender associated with different disposal methods?

RQ3. What is the most important issue people consider when deciding how to dispose of leftover medications?

RQ4. Is there a relationship between an individual's primary disposal issue and drug disposal method chosen?

The overall aim of *Study 2*, which took place at a pharmaceutical take-back event, was to describe people who participated in a formal disposal program, as well as to explore event participants' perceptions and preferences regarding disposal.

RQ5. Who participates in pharmaceutical take-back programs?

RQ6. Among those participating in pharmaceutical take-back, what are their preferences and perceptions regarding other methods?

Study 3, which entailed an online experimental survey, explored whether participants' disposal method choice might be influenced by whether the problem was presented as an environmental issue versus a public health issue.

RQ7. Does presenting drug disposal as a public health versus environmental problem influence people's preferences for drug disposal method?

Prior to conducting the three studies, insights were gathered through interviews with key informants in Tompkins, Monroe, and Erie counties in New York State who were involved in or had knowledge of pharmaceutical take-back programs, including professionals who interact with take-back program participants.

METHOD

Study 1: Empire State Poll

Study Population

The Empire State Poll (ESP) is a general, random-sample survey of adults (ages 18 and over) residing in New York State conducted annually by the Survey Research Institute (SRI). The 2017 survey was conducted using computer-assisted telephone interviewing from February 2 to April 8, 2017. Eight hundred people participated in the poll.

Sampling

The ESP is designed to ensure every New York State household has an equal chance to be included in the survey, and that every adult in a sampled household has an equal chance of being included. The sample was obtained through random-digit dialing to both cellular and landline numbers from a purchased list (Marketing Systems Group). The sampling frame was split between upstate and downstate New York (400 respondents each) to obtain enough responses from smaller geographic regions for comparisons among regions. With 800 respondents, the results were expected to vary no more than 3.5 percentage points from what would be measured by polling the entire state population (at a 95% confidence level).

With the random sampling frame, the data can be generalized to the entire state by weighting downstate and upstate responses. Weights were calculated by SRI using population figures from 2013 American Community Survey one-year estimates. All data reported here were analyzed using weights.

Constructs and Measures

The ESP includes an annual core question set that explores issues related to work, community, government, and the economy, as well as demographic questions similar to those on the U.S. census. Each poll also includes questions on special topics, which are contributed by various researchers. The 2017 poll included two questions for the current drug disposal behavior study.

Drug disposal method. Participants were first asked if they had ever disposed of any medication. If they answered yes, they were then asked to report the method of disposal they had used most recently. Method options were derived from the literature and expert interviews to ensure the options were relevant and representative of methods available to most people. The options included:

- Dropped it off at a medication take-back event in my community.
- Took it to a permanent public drop-off site in my community.
- Mailed it through a pharmacy program.
- Dropped it off at a pharmacy.
- Flushed it down the toilet or washed it down the sink.
- Threw it out in the trash.

Most important factor for deciding on a disposal method. A follow up question asked participants who had disposed of medication to report "the most important factor you considered when you decided how to dispose of the medication." Choices were derived from the literature and expert interviews. The interviewer read the following list of choices (if a respondent expressed uncertainty about their exact reason or showed any hesitation, then the interviewer would read through the text in the parentheses after the choices below, but most people had an immediate answer that clearly fit into one of the options).

- Convenience (such as how much time disposal takes, how far I need to travel for disposal, or my familiarity with the disposal place).
- Preventing environmental impacts (such as water pollution).
- Preventing someone from taking the medication illegally (which might contribute to drug abuse problems).
- Preventing an accident (such as a child taking the medication).

SRI pilot-tested the questions with 25 participants. Based on participant responses and SRI input, questions were revised for succinctness and clarity for the poll.

Study 2: Take-Back Event Survey

Study Population

The sample for Study 2 was drawn from 71 attendees at a pharmaceutical take-back event in a rural central New York community. The event took place at a community fire station on a Saturday in April of 2016 and coincided with the Drug Enforcement Agency's annual take-back date. Local officials hosted the event and advertised via newspaper, radio, posters, and listserv (email) messages. A large sign outside the fire station alerted community members to the event as well.

At the event, attendees were asked to participate in a voluntary study that was approved by the researcher's institutional review board. Ninety-four percent (67 of 71) of event attendees agreed and completed a survey.

Survey Development

In addition to existing literature, survey development was based in part on interviews with seven experts involved in some aspect of drug disposal, including waste management (solid waste, wastewater, recycling), environmental management, and public health. Interviews were used to ensure adequate breadth in the survey in terms of disposal methods, reasons why people might have leftover medications, and concerns people might have regarding disposal. Two experts reviewed a draft of the local event survey and offered feedback regarding question content and clarity. The survey was also pilot-tested with university students to check clarity and question wording and to estimate completion time.

Constructs and Measures

Concerns about health and environment. Take-back event participants reported their level of agreement with five statements that began, "Disposing of unwanted medications is important because…" Two statements related to the environment (it can prevent medicine from entering waterways, it can protect the environment) (Cronbach's Alpha = 0.95). and three related to public health (it can prevent accidental poisoning, it can prevent someone else from taking medication for nonmedical reasons, it can protect people's health) (Cronbach's Alpha = 0.80).

Participants indicated their level of agreement with the statements on a scale of 1 to 7, with one being strongly disagree and 7 being strongly agree. For analysis, scores from the two environment items were averaged and scores from the three health items were averaged.

Convenience and difficulty. Participants responded to a series of seven statements about convenience and difficulty associated with planning to attend the event, storing unwanted medications, and traveling to the event (Cronbach's Alpha = 0.56). Responses were given on a Likert scale from 1 to 7, where 1 equals strongly disagree and 7 equals strongly agree, and were averaged by topic for analysis.

Preference and intention. Participants were asked what method they would prefer to use for disposing of medication in the future, as well as what they intended to use. Method options were derived from the literature and expert interviews and included:

- A periodic drop-off event at a pharmacy.
- To flush medications down the toilet or wash them down the drain at home.
- A mail back program.
- A drop-off program at the police station, available all hours.
- To throw medications in the trash.
- A periodic drop-off event at a local public solid waste facility.
- A drop-off program at my pharmacy, available during pharmacy hours.

Familiarity. Participants were also asked to rate their familiarity with the places associated with the medication disposal methods, namely:

- A local police station.
- A local public waste facility.
- My doctor's office.
- A local post office.
- My pharmacy.

Participant demographics. Data collected via the event survey included age, income, gender, miles traveled to the event, and type of transportation taken to the event.

Procedure

The take-back event was led by a county official and overseen by a law enforcement officer. When people arrived at the event, volunteers greeted them, told them how the medication drop-off process worked, and told them that researchers were also present to collect data for a voluntary study. After completing the medication drop-off, a researcher asked attendees if they would like to participate in the study by completing a brief survey that was expected to take a few minutes to complete. A team of researchers administering the survey was available to help participants read the survey and answer questions as necessary. One participant with poor eyesight asked that the survey be read aloud. The survey took approximately 5-10 minutes to complete.

Study 3: Experimental Survey

Study Population

Participants for Study 3 were recruited via Research Match, an online databank of study volunteers ("ResearchMatch," n.d.). Research Match is a free service that was created by the U.S. National Institutes of Health and several universities and other partner organizations to help researchers recruit participants for health-related studies. The databank consists of people who suffer from a health condition and are interested in participating in a study specific to that condition, as well as healthy volunteers who are interested in contributing to the greater good. When volunteers sign up, they agree to be contacted by researchers. Approximately 100,000 people in the U.S. (mostly adults over age 18) were enrolled in Research Match at the time of this study.

Procedure

Recruiting within the Research Match system consists of a number of steps. First, researchers can choose basic criteria for participants, such as geographic location or gender. In the case of this study, the only limitation set was that participants had to be at least 18 years of age. Second, researchers specify the number of people to contact, up to a maximum of 1,500 at a time. The Research Match system then randomly selects the specified number of people among those in the database who meet the criteria and sends them a message from the researcher. The message must include IRB-approved consent language. For this study, the initial message also stated that to participate volunteers must "currently have a medication in your home (any type, over-the-counter or prescription)." Upon receiving the message from Research Match, potential participants can either say, "yes" to being contacted directly by the researcher, or "no." (Because the messages are sent through the Research Match system, there is no way to know if any messages "bounced" due to bad addresses. Also, many people do not open the initial contact from Research Match, so may not actively decline to participate based on any information about a particular study.[2]) Finally, Research Match provides researchers with the email addresses of those people who responded "yes" to the initial contact.

At this point, recruiting happens directly between the researcher and potential participants via email. The pharmaceutical survey was administered online through Qualtrics. Each potential participant (those who responded "yes") received a unique link to the survey. They were sent two reminders if they did not complete the survey.

A pilot study administered prior to the full study provided an opportunity to check the mechanics of the Research Match and Qualtrics systems and to test the survey questions. From 951 initial requests, 74 direct survey links were sent (7.8% initial response) and 61 participants completed the pilot survey, for a 6.4 percent completion rate. Based on the pilot study, minor wording changes were made to the recruitment message to encourage participation and minor formatting and wording adjustments were made for clarity.

For the full study, the goal was to collect approximately 600 surveys to ensure enough participants per experimental condition and to ensure enough participants for an associated study where fewer people were likely to qualify. Based on the completion rate for the pilot study, the

[2] In the version of Research Match that was operating during the pilot, researchers could see a report of the number of people who actively replied yes, actively replied no, or did not open the message. Unfortunately, this feature was removed during the system update, and the data was not retained.

plan was to initiate contact with about 10,000 people via Research Match. The process had to be repeated a number of times, because the system limits the size of batches.

Unfortunately, between the pilot study and the full study, the Research Match website was overhauled, which resulted in technical problems. In the midst of contacting potential participants for the full study, Research Match notified researchers that messages sent for a period of time after the system came back online were blank. Based on that information, it is difficult to determine an accurate response rate for the present study.

A total of 16,560 initial contacts were made via the Research Match system, but at least 6,900 were likely blank. Out of approximately 9,660 initial contacts that contained a message, 953 people (9.9% response) agreed to be contacted, 730 began the survey, and 682 completed it, for a 7.1 percent completion rate, which was similar to the pilot response.

Constructs and Measures

Public health vs. environmental problem (independent variable). Participants were assigned to one of three experimental conditions (drug abuse/public health, environment, or neutral) and given a corresponding statement regarding drug disposal (see Table 1). The statements were adapted from federal agency websites regarding drug disposal, including those of the Drug Enforcement Agency and the Environmental Protection Agency.

Drug disposal method. Participants were asked to report what method they most recently used to dispose of unwanted medications (if any). Disposal method options mirrored those used in the previous two studies (i.e., take-back event, permanent drop-off site, mail, pharmacy, flush, trash).

Table 1: Survey Conditions

Experimental Condition	Description Given to Participants
A (drug abuse/public health)	According to the National Survey on Drug Use and Health, more than 6 million Americans abuse prescription drugs each year. A majority of people abusing prescription drugs obtained the drugs from family and friends, including taking them from a home medicine cabinet. There are several ways to dispose of expired, left over, or other unwanted medications to help prevent the misuse or abuse of prescription drugs. The following questions ask for your thoughts on different disposal methods.
B (environment)	Scientific studies have detected medications, including prescription drugs, in surface waters, treated drinking water, and treated wastewater, and in fish. There are several ways to dispose of expired, left over, or other unwanted medication to reduce the introduction of potentially harmful substances into the environment, particularly into water. The following questions as for your thoughts on different disposal methods.
C (neutral)	Researchers estimate that up to 30% of medications people buy are never used. There are several ways to dispose of expired, left over, or other unwanted medications. The following questions as for your thoughts on different disposal methods.

Preference for, intention to use, perceived difficulty of disposal methods. Participants were asked to report their level of agreement with three statements regarding disposal for eight disposal methods. The statements were: in my community I would prefer…; the next time I need to dispose of a medication I intend to…; and it would be difficult (require a lot of effort) to dispose of medication…" The methods were:

- A mail back program.
- Throw medications in the trash.
- A drop-off program at a pharmacy, available during pharmacy hours.
- A drop-off program at a police station, available all hours.
- A drop-off event at a local public facility.
- To flush medications down the toilet or wash them down the drain at home.

- A drop-off event at a pharmacy.
- Purchasing and using an at-home drug deactivation kit.[3]

Participant demographics. Data collected via the survey included age, income, and gender.

Similar to the local event survey, the online survey was first pilot-tested with university students to check clarity and question wording and to estimate completion time.

Analytic Strategy

All statistical analyses were performed using IBM SPSS Statistics for Mac (version 24)

Study 1: Empire State Poll

RQ1: How do people dispose of unwanted medications? To address the question of how people dispose of unwanted medication, drug disposal method data were analyzed with descriptive statistics (frequencies and percentages).

RQ2: Are age or gender associated with different disposal methods? Chi square analyses were used to test the relationship between age and disposal method and gender and disposal method.

RQ3. What is the most important factor people consider when deciding how dispose of leftover medications? Data on most the important factor considered when choosing a disposal method were analyzed with descriptive statistics**.**

RQ4. Is there a relationship between primary consideration and drug disposal method chosen? A chi-square analysis was used to test the relationship between the most important factor identified by participants and the participants' chosen drug disposal method.

[3] Commercial at-home drug deactivation kits began to gain interest as the research project progressed, and so were added to the list of options for the experimental survey.

Study 2: Local Take-Back Event Survey

RQ5: Who participates in pharmaceutical take-back programs? Data from the in-person survey were analyzed using descriptive statistics to develop an overall profile of participants' demographics, along with information on how they heard about and traveled to the event.

RQ6: Among those participating in pharmaceutical take-back, what are their preferences and perceptions regarding various disposal methods Wilcoxon signed-rank tests were used check for differences among participants' ratings of different disposal methods.

Study 3: Experimental Survey

RQ7: Does presenting drug disposal as a public health versus environmental problem influence people's preferences for drug disposal method? One-way ANOVA was used to test the effects of experimental conditions in Study 3.

RESULTS

Study 1: Empire State Poll

RQ1: How do people dispose of unwanted medications?

More than 80 percent of Empire State Poll participants reported that they had disposed of a medication in the past (n=798). Of those who had disposed of medication (n=646), a majority reported most recently throwing medication in the trash (52%) (see Figure 1). Another 16.4 percent flushed medication down the toilet or washed it down a sink drain. Based on written comments in Study 3, many "other" responses (4.2%) likely refer to some type of home disposal as well (burning, mixing medications with something before throwing away, etc.).

About one-quarter reported using some type of drop-off or take-back program. Pharmacy (13.8%) and permanent community drop-off sites (8.2%) were cited most frequently. Less than five percent had used a take-back event for their most recent medication disposal.

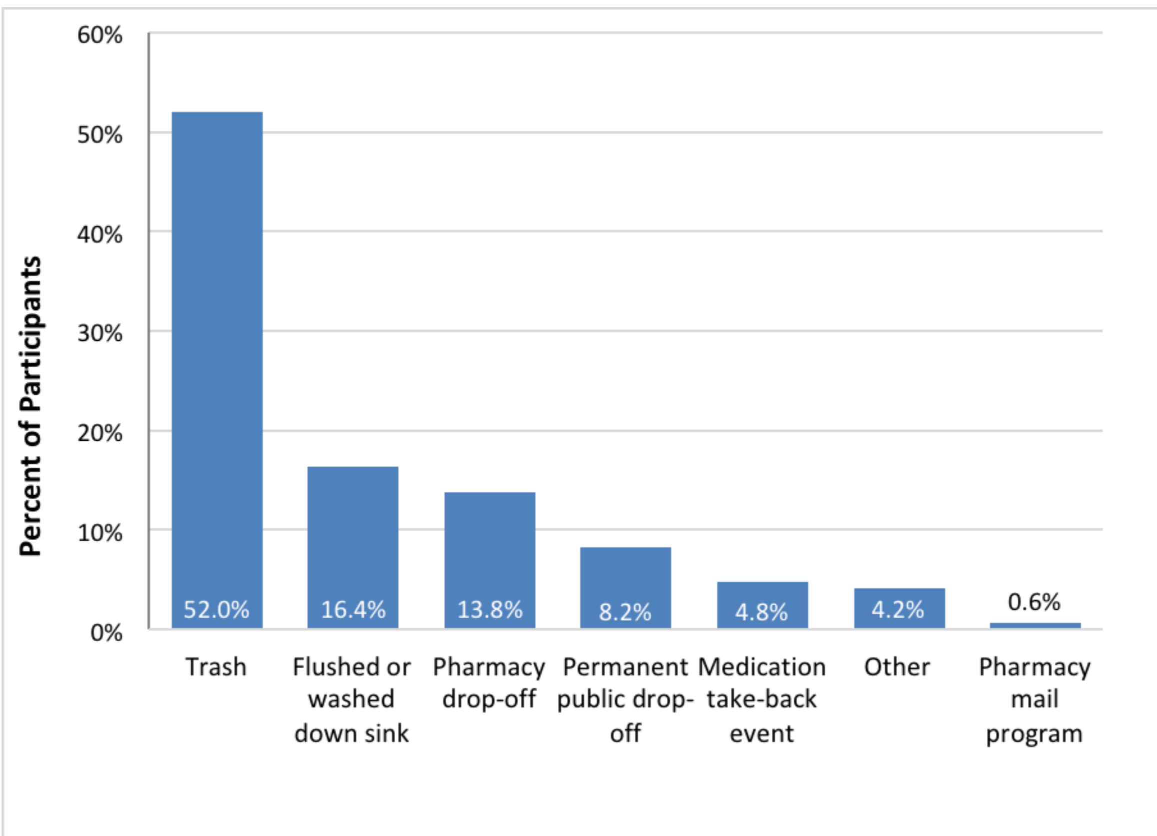

Figure 1: Most recent medication disposal method used by Empire State Poll participants.

RQ2: Are age or gender associated with different disposal methods?

Among Empire State Poll participants, while age was not a significant factor for whether a person had disposed of medication previously or not, X^2 (5, n=798) = 6.244, p=.283 (see Table 2), there was a main effect of age on disposal method, X^2 (5, n=646) = 24.023, p<.001.[4] Older adults (65+) were more likely to use out-of-home (take-back or drop-off) methods, while young adults (18-24) were less likely to do so (see Table 3).

Among ESP participants, there was no significant relationship between gender and disposal method, X^2 (1, n=646) = 3.178, p=.075. In addition, there was no significant association between income and disposal method, X^2 (8, n=631) = 4.409, p=.819.

Table 2: Age and Past Disposal, ESP Participants

		Past Disposal		
Age Category		Have disposed before	Have not disposed before	Total
18-24	Count	64 (76.2%)	20 (23.8%)	84
	Standardized residual	-0.5	1.0	
25-34	Count	120 (85.7%)	20 (14.3%)	140
	Standardized residual	0.6	-1.3	
35-44	Count	108 (78.3%)	30 (21.7%)	138
	Standardized residual	-0.4	0.7	
45-54	Count	142 (84%)	27 (16%)	169
	Standardized residual	0.4	-0.9	
55-64	Count	103 (81.7%)	23 (18.3%)	126
	Standardized residual	0.1	-0.2	
65+	Count	109 (77.3%)	32 (22.7%)	141
	Standardized residual	-0.5	1.0	
Total	Count	646 (81%)	152 (19%)	798

[4] For several analyses, disposal methods were combined into two categories: at home disposal (flush, trash, other) and out-of-home disposal (take-back events, drop off locations, mail back), as some combinations had too few cases for analysis.

Table 3: Age and Disposal Method, ESP Participants

Age Category		Disposal Method: Take-back or drop off	Disposal Method: Flush, trash, other	Total
18-24	Count	9 (14.1%)	55 (85.9%)	64
	Standardized Residual	-2.1	1.3	
25-34	Count	27 (22.3%)	94 (77.7%)	121
	Standardized Residual	-1.1	0.7	
35-44	Count	21 (19.4%)	87 (80.6%)	108
	Standardized Residual	-1.6	1.0	
45-54	Count	44 (31.0%)	98 (69.0%)	142
	Standardized Residual	0.8	-0.5	
55-64	Count	31 (30.4%)	71 (69.6%)	102
	Standardized Residual	0.5	-0.3	
65+	Count	46 (42.2%)	63 (57.8%)	109
	Standardized Residual	2.9	-1.8	
Total	Count	178 (27.6%)	468 (72.4%)	646

RQ3: What is the most important factor people consider when deciding how to dispose of leftover medications?

Empire State Poll participants who had disposed of medication named convenience most often as the most important factor influencing their choice of disposal method (44.7%). They cited concern related to the environment (21.3%) more often than concern about illegal drug use (15.1%), though if illegal drug use is combined with concern about potential accidents (18.8%), public health concerns outweighed environmental concerns (see Figure 2).

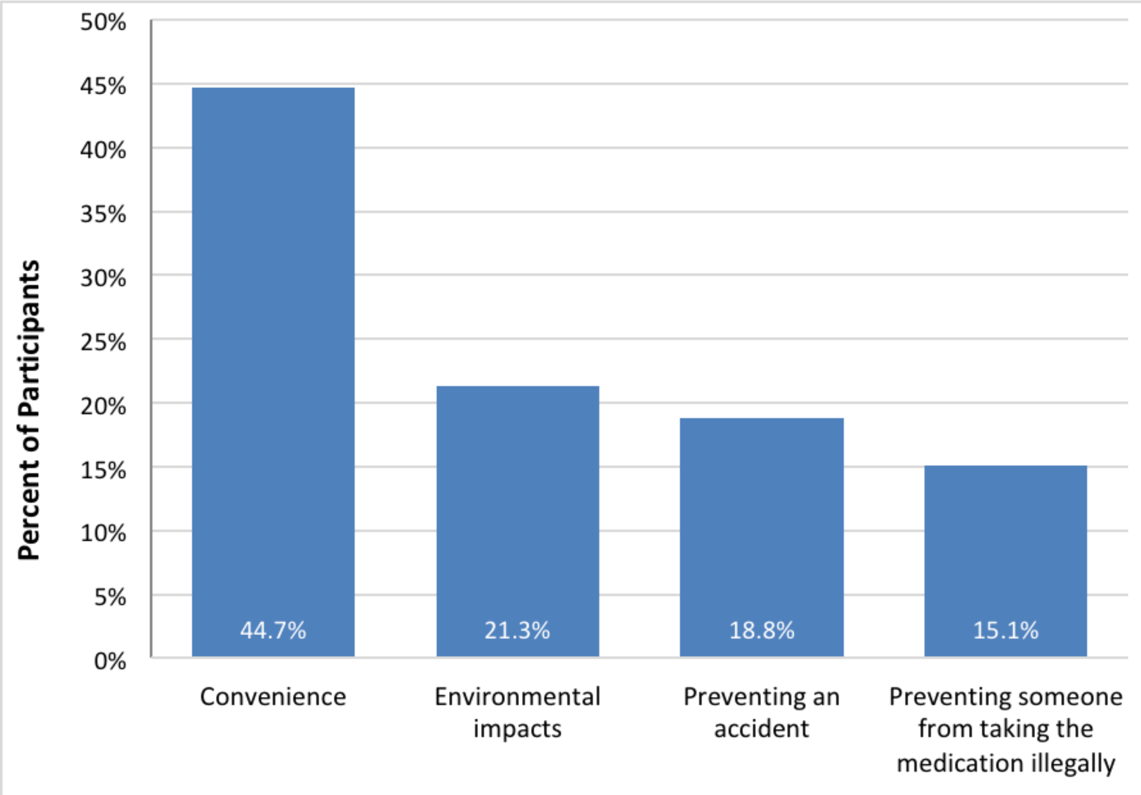

Figure 2: Most important issue influencing choice of disposal method, ESP participants.

RQ4. Is there a relationship between primary consideration and drug disposal method chosen?

A chi-square test of the ESP data showed a main effect of issue on disposal method, X^2 (3, n=645) =199.335, p<0.001 (see Table 4). Looking at the individual relationships more closely, people who cited convenience as the main issue influencing in their choice of disposal method were much more likely to dispose of medications at home via trash or flushing (57.6%) than out of home at a drop-off location or event (10.2%). People who cited environmental impacts showed the opposite preference, choosing out-of-home methods (55.1%) over at-home methods (8.5%). There were no significant associations with disposal method and interest in preventing illegal consumption or accidents.

Table 4: Important Issues Influencing Choice of Disposal Method, ESP Participants

		Disposal Method		
Issue Influencing Disposal Choice		**Out of Home**	**In Home**	**Total**
Convenience	Count	18 (6.3%)	270 (93.8%)	288
	Standardized residual	-6.8	4.2	
Environmental impacts	Count	97 (70.8%)	40 (29.2%)	137
	Standardized residual	9.8	-6.0	
Preventing someone from taking the medication illegally	Count	34 (34.7%)	64 (65.3%)	98
	Standardized residual	1.4	-0.9	
Preventing an accident	Count	27 (22.1%)	95 (77.9%)	122
	Standardized residual	-1.1	0.7	
Total	Count	176 (27.3%)	469 (72.7%)	645

Study 2: Local Take-Back Event Survey

RQ5: Who participates in pharmaceutical take-back programs?

A total of 149 pounds of medication was collected during the four-hour take-back event in April 2016. Nearly half of participants (46.3%) had attended a prior take-back event. Table 5 provides a snapshot of the 67 local event participants who completed a survey, with demographic comparisons to county, state, and national figures.

Participants were older than comparison populations. Nearly 70 percent were age 55 and older. Few (approximately 3%) were under age 35.

More than two-thirds of study participants were female. However, some event participants arrived with a partner, while only one member of each party filled out a survey. The number of multi-person parties was not counted. Therefore, it is possible that the gender imbalance is somewhat overstated.

Table 5: Event Participant Demographics

Variable	Study Participants	Tompkins County	New York State	U.S.
Age (18+) (n= 64)				
18-24	0.0%	31.4%	13.2%	12.1%
25-34	3.1%	16.1%	17.7%	18.0%
35-44	9.4%	12.2%	17.3%	16.2%
45-54	18.8%	14.1%	19.1%	16.8%
55-64	31.3%	13.3%	15.3%	16.7%
65+	37.5%	12.9%	17.4%	20.2%
Gender (n=62)				
Female	69.4%	50.8%	51.5%	50.8%
Male	30.6%	49.2%	48.5%	49.2%
Education (n=60)				
Less than high school degree	1.7%	5.4%	14%	13%
High school degree	15.0%	19.9%	26.4%	27.5%
Some college	3.3%	13.3%	16.1%	21%
Associates Degree	6.7%	9.7%	8.6%	8.2%
Bachelor’s Degree	25.0%	22.2%	19.7%	18.8%
Some Graduate Education	3.3%	--	--	--
Graduate Degree	45.0%	29.5%	15.1%	11.5%
Income (n=54)				
less than 20k	3.7%	20.6%	17.6%	17.2%
20-34.9k	7.4%	14.0%	13.4%	15.1%
35-49.9k	14.8%	12.3%	11.5%	13.2%
50-74.9k	16.7%	17.8%	16.2%	17.8%
75-99.9k	20.4%	11.3%	11.9%	12.2%
100-149.9k	25.9%	12.2%	14.6%	13.5%
150-199.9k	3.7%	5.9%	6.7%	5.4%
200k and up	7.4%	5.8%	8.0%	5.7%

(U.S. Census Bureau, 2011, 2018a, 2018b)

Participants were more educated than state and national populations. Nearly three-quarters had at least a bachelor's degree, compared to only about one-third statewide and nationally. County residents' educational attainment (51.7% with at least a bachelor's degree) is also higher than state and national figures, so some of the difference between event participants and state and national populations could be attributed to the locale and its proximity to a large university.

Finally, nearly 60 percent of event participants reported household income $75,000 or higher, versus 35-41 percent of county, state, and U.S. residents. Few participants reported an income below $20,000 (3.7%).

For comparison, demographics for Empire State Poll respondents who reported using some form of take back are shown in Table 6. Respondents were older than the county, state and national comparison populations, with the largest differences in the 18-24 (4.9% for Empire out-of-home disposal participants vs. 13.2% of New York State residents), 45-54 (24.6% vs. 19.1%), and 65+ (25.9% vs. 17.4%) categories. The differences between ESP respondents and state residents were not as extreme as those between local event participants and state residents, however. ESP respondents were split nearly evenly in terms of gender (52% male, 48% female). ESP respondents reported higher education levels than state and national populations. About half had at least a bachelor's degree, compared to about one-third statewide and nationally. Finally, there was little difference between the Empire respondents and other populations in the highest household income categories (41.9% of Empire respondents' household income greater than $75,000 vs. 41.2% for the state). However, similar to the local event participants, few ESP respondents reported an income below $20,000 (6%).

Among take-back event participants, the primary reasons people cited for disposing of medications were that the medication was no longer needed (had changed, was overprescribed, not wanted) (58.3%), the medication had expired (36.7%), or the person taking the medication had passed away (5.0%) (n=60).

Table 6: Empire Poll Participants Who Used a Form of Take-Back for Disposal

Variable	Empire Participants	Tompkins County	New York State	U.S.
Age (18+) (n= 64)				
18-24	4.9%	31.4%	13.2%	12.1%
25-34	15.0%	16.1%	17.7%	18.0%
35-44	12.0%	12.2%	17.3%	16.2%
45-54	24.6%	14.1%	19.1%	16.8%
55-64	17.7%	13.3%	15.3%	16.7%
65+	25.9%	12.9%	17.4%	20.2%
Gender (n=62)				
Female	48%	50.8%	51.5%	50.8%
Male	52%	49.2%	48.5%	49.2%
Education (n=60)				
Less than high school degree	2.2%	5.4%	14%	13%
High school degree	23.1%	19.9%	26.4%	27.5%
Some college	22.6%	13.3%	16.1%	21%
Associates Degree	26.4%	9.7%	8.6%	8.2%
Bachelor's Degree	25.0%	22.2%	19.7%	18.8%
Graduate Degree	24.7%	29.5%	15.1%	11.5%
Income (n=54)				
less than 20k	6.0%	20.6%	17.6%	17.2%
20-34.9k		14.0%	13.4%	15.1%
35-49.9k	20-50K:	12.3%	11.5%	13.2%
50-74.9k	26.7%	17.8%	16.2%	17.8%
75-99.9k	22.8%	11.3%	11.9%	12.2%
100-149.9k	11.9%	12.2%	14.6%	13.5%
150-199.9k	16.2%	5.9%	6.7%	5.4%
200k and up	>150: 13.8%	5.8%	8.0%	5.7%

(U.S. Census Bureau, 2011, 2018a, 2018b)

Take-back event participants reported their level of agreement with several statements about the importance of disposing of unwanted medications. In general, participants reported very strong agreement with both environmental ($\bar{x}$=6.8, s.d.=0.59) and public health ($\bar{x}$=6.5, s.d.=0.77) statements (on a scale from 1 to 7, where 7 indicated strong agreement).

Participants were asked what they would have done if they had not attended the take-back event. Many reported that they would have held on to unwanted drugs in the home (44.8%) (see Figure 3). More than 20 percent thought they would have used a police station drop-off (though only 8.8 percent reported having used one of the several 24/7 police disposal sites available in the county in the past). Few suggested they would have flushed (4.5%) or thrown away the medications (11.9%).

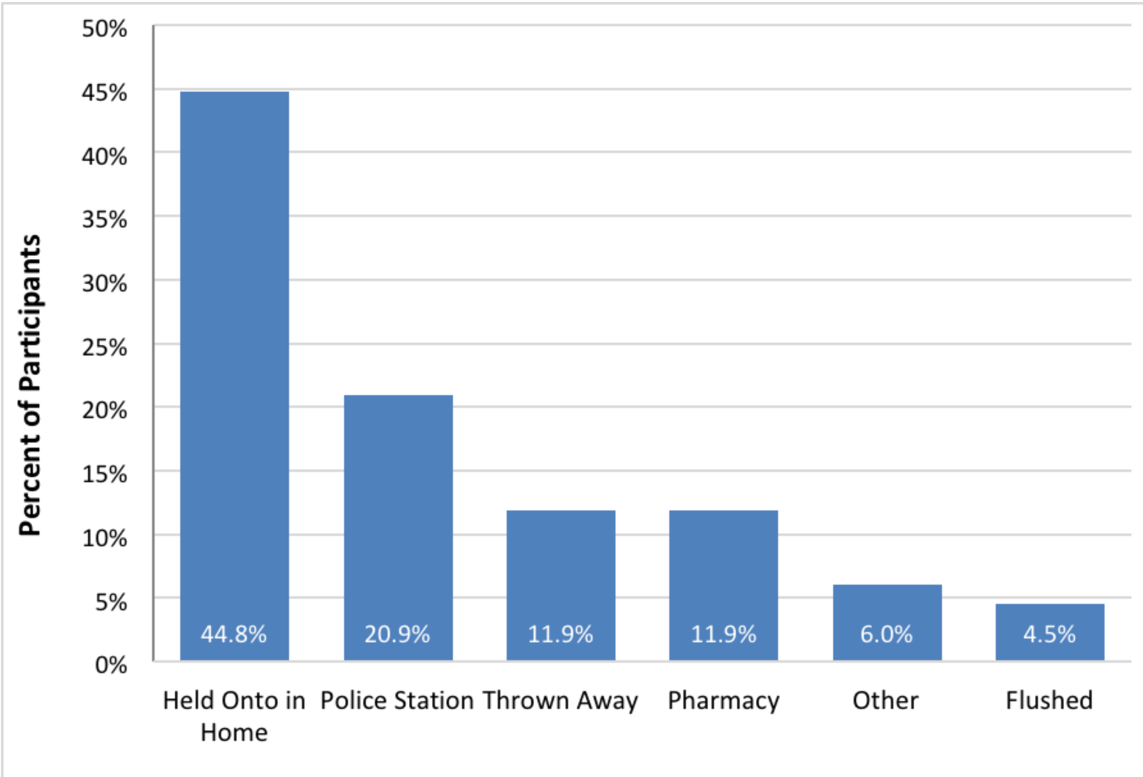

Figure 3: Action take-back event participants would have taken if they had not disposed of medications at the event.

On the whole, take-back participants reported little difficulty or inconvenience associated with participation in the take-back event (for a 7-item scale, with a scale from 1 to 7, where 1 equals strongly disagree and 7 equals strongly agree, $\bar{x}$=2.23, s.d.=0.84). On specific questions regarding medication storage, participants indicated they experienced some difficulty ($\bar{x}$=3.47, s.d.=1.98) and inconvenience ($\bar{x}$=3.71, s.d.=2.08) A little less than half of participants kept their unwanted medications in the "normal" place where they stored other medications (46.9%), while the remainder kept them elsewhere (53.1%). People reported storing medications on the kitchen counter, in a cupboard, in a desk, in a drawer, in the garage, in the attic, on a spice rack, near the recycling, in a closed storage area, in a locked cabinet, and in a box or plastic bag.

Most participants traveled to the take-back event by personal car (95.3%). A majority traveled five or fewer miles (see Table 7).

TABLE 7: Travel Mode for Take-Back Event Participants

Variable	Event Participants
Method of travel	
Personal car	95.3%
Shared ride	1.6%
Walked	3.1%
Miles traveled	
<2	20%
2-5	55%
6-10	18.3%
>10	6.7%
Mean	5.0
Median	3.0
(n=67)	

RQ6. Among those participating in pharmaceutical take-back, what are their preferences and perceptions regarding other methods?

Take-back event participants were asked about their preference and intention to participate in several different disposal methods. Participants expressed the strongest preference for a pharmacy drop-off, either event-based or during regular pharmacy hours, and the weakest for flushing or throwing the medications out at home (see Table 8). A Wilcoxon signed-rank test showed a significant preference for the pharmacy drop-off during regular pharmacy hours over an event at a public waste facility (Z=-2.911, p=.004). There was no significant difference between preference for a pharmacy event and an event at a public waste facility.

TABLE 8: Preferences for Future Disposal, Take Back Event Participants
(1=strongly disagree prefer, 7=strongly agree prefer)

Disposal Method (most to least preferred)	**Mean (s.d)**
A drop-off program at my pharmacy, available during pharmacy hours (n=56)	5.98 (1.57)
A periodic drop-off event at a pharmacy (n=55)	5.49 (1.91)
A periodic drop-off event at a local public waste facility (n=54)	4.89 (2.04)
A drop-off program at the police station, available all hours (n=53)	4.77 (1.97)
A mail-back program (n=51)	1.73 (1.39)
To throw medications in the trash at home (n=52)	1.25 (0.91)
To flush medications down the toilet or wash them down the drain at home (n=52)	1.10 (0.30)

Participants also indicated they were most likely to use a pharmacy drop-off in the future (see Table 9). The difference between ratings for intention to use a pharmacy drop-off during regular hours and a local waste public facility event fell just short of significance at the .05 level (Z=1.946, p=.052).

TABLE 9: Intention for Future Disposal, Take-Back Event Participants
(1=strongly disagree, 7=strongly agree)

Disposal Method (most to least intention to use)	**Mean (s.d.)**
A drop-off program at my pharmacy, available during pharmacy hours (n=54)	5.83 (1.81)
A periodic drop-off event at a pharmacy (n=54)	5.35 (2.07)
A periodic drop-off event at a local public waste facility (n=55)	5.04 (2.15)
A drop-off program at the police station, available all hours (n=53)	4.19 (2.31)
A mail-back program (n=50)	1.60 (1.21)
To throw medications in the trash at home (n=50)	1.28 (1.03)
To flush medications down the toilet or wash them down the drain at home (n=51)	1.12 (0.43)

Take-back event participants were asked to rate the difficulty of several drug disposal methods. Participants rated a mail-back program for drug disposal most difficult, and a business hours drop-off at a pharmacy least difficult (see Table 10). Flushing or washing medications down the drain at home was rated second-most difficult. However, questions from a few participants during the event indicated that they considered this option "emotionally" difficult (i.e., though it was physically easy, they could not bring themselves to do it). There was no significant difference between a local public waste facility event and either pharmacy option.

TABLE 10: Difficulty of Disposal Methods, Take-Back Event Participants
(1=strongly disagree difficult, 7=strongly agree difficult)

Disposal Method (most to least difficult)	**Mean (s.d)**
A mail-back program (n=55)	4.27 (2.32)
To flush medications down the toilet or wash them down the drain at home (n=51)	3.41 (2.67)
To throw medications in the trash at home (n=51)	3.31 (2.59)
A drop-off program at the police station, available all hours (n=53)	2.64 (1.89)
A periodic drop-off event at a local public waste facility (n=54)	2.48 (1.77)
A periodic drop-off event at a pharmacy (n=56)	2.20 (1.80)
A drop-off program at my pharmacy, available during pharmacy hours (n=54)	1.96 (1.60)

Finally, take-back event participants indicated their level of familiarity with several locations that might offer drug disposal (see Table 11). The location of a person's pharmacy was rated most familiar, and the local police station least. A Wilcoxon signed-rank test showed a significant difference between familiarity with a pharmacy and a local police station (Z=-4.12, $p < .001$.), as well as between a pharmacy and a local public waste facility (Z=-4.08, $p < .001$.).

TABLE 11: Familiarity with Potential Disposal Locations, Take-Back Event Participants
(1=strongly disagree familiar, 7=strongly agree familiar)

Disposal Method (most to least familiar)	**Mean (s.d.)**
My pharmacy (n=56)	6.52 (1.29)
A local post office (n=55)	6.30 (1.54)
My doctor's office (n=55)	5.98 (1.79)
A local public waste facility (n=53)	5.08 (2.17)
A local police station (n=54)	5.00 (2.10)

Study 3: Experimental Survey

Participants and Their Past Disposal Behavior

Online survey respondents were largely female (80.5%) and white (83.3%). Forty-three percent were aged 55 or over and more than two-thirds had a college degree (70.6%). A little more than half earn less than $75,000 (52.4%), while about a third earn more than $100,000. (A full table with demographics is provided in the Appendix.)

Of 682 respondents to the experimental survey, 95 percent (648) reported having disposed of a medication in the past. Figure 4 shows how they disposed of a medication most recently. A majority, 52 percent threw the medication in the trash. Another 15 percent flushed the medication or washed it down a drain. A little less than a third participated in some form of take-back (12.2% an event, 10.8% a permanent drop off, 6.8% a pharmacy, and 0.6% a mail back).

Nearly all (95%) of experimental survey participants had disposed of a medication in the past. There was a main effect of age on disposal method X^2 (5, n=632) = 51.371, p< .001. Adults aged 18 to 34 were less likely to have used an out of-home disposal method than an at-home method. Older adults, particularly in the 45-54 age category, were more likely to have used an out-of-home than an at-home method (see Table 12).

Table 12: Age and Disposal Method, Experimental Survey

		Disposal Method		
Age Category		**Take-back or drop off**	**Home flush, trash**	**Total**
18-24	Count	3 (6.8%)	41 (93.2%)	44
	Standardized Residual	-3	2	
25-34	Count	16 (14%)	98 (86%)	114
	Standardized Residual	-3.4	2.3	
35-44	Count	23 (26.7%)	63 (73.3%)	86
	Standardized Residual	-0.9	0.6	
45-54	Count	37 (33.9%)	72 (66.1%)	109
	Standardized Residual	0.3	-0.2	
55-64	Count	75 (46.3%)	87 (52.7%)	162
	Standardized Residual	3.2	-2.2	
65+	Count	49 (41.9%)	68 (58.1%)	117
	Standardized Residual	1.9	-1.3	
Total	Count	203 (32.1%)	429 (67.9%)	632

Among experimental survey participants, there was no significant relationship between gender and disposal method X^2 (2, n=619) = 1.709, p=.425. In addition, there was no significant association between income and disposal method X^2 (7, n=611) = 1.764, p=.972.

RQ7: Does presenting drug disposal as a public health versus environmental problem influence people's preferences for drug disposal method?

Based on results of one-way ANOVA analyses, presenting drug disposal as a public health, environmental, or general issue had little impact on people's expressed preferences for disposal method, perceived difficulty of disposal method, or intention to use a disposal method.[5] There was no main effect of experimental condition on preference for any of the eight disposal methods rated by participants. There was no main effect of experimental condition on the disposal method participants intend to use the next time they have leftover medications. There was a main effect of experimental condition on people's perception of the difficulty of throwing leftover medications in the trash [$F(2, 675) = 3.256$, $p = .039$)]. Tukey post hoc tests showed a significant difference between the public health and environmental conditions, with participants in the environmental condition rating trash more difficult than participants in the public health group. However, most participants disagreed that using the trash was difficult (i.e., the difference was not of practical significance). Additional analyses showed no significant differences within groups by gender, income, or age, and no interaction effects between gender, income, or age and the experimental condition.

[5] A separate Chi Square analysis with dependent variables (difficulty, intention, preference) recoded into 2 categories (yes/no) produced the same results.

DISCUSSION

Conclusions

Nearly 50 percent of Americans responding to a recent national survey reported having taken a prescription medication in the past 30 days, and the percent of the population taking prescription medications is growing (Centers for Disease Control, National Center for Health Statistics, 2017). Considering over-the-counter drug use together with prescription drug use, medication use is prevalent and widespread. Drug disposal has become a common activity as well. Ninety-five percent of experimental survey participants and more than 80 percent of Empire Poll participants reported having disposed of unwanted medications in the past. Given the scope of activity and the serious environmental and public health implications, drug disposal behavior is an important issue. The three studies described above were aimed at providing insights into drug disposal behavior, specifically by addressing research questions regarding how people dispose of unwanted medications, what influences their choices, and what they prefer.

Based on data from the Empire State Poll and experimental survey, the majority of people dispose of unwanted medications in the home. The most common method of disposal is to throw medication in the trash (52% of both ESP and experimental survey participants). Flushing a medication down a drain or toilet is the next most common at-home disposal method (16.4% ESP, 15% experimental survey). Fewer people engage in drop-off or take-back behaviors, including pharmacy- and community-based drop-off sites or events.

Take-back event participation is uncommon. Among experimental survey participants, 12.2 percent reported having disposed of a medication most recently at an event, versus 4.8 percent of ESP participants. ESP participants used a pharmacy (13.8%) or permanent community drop-off (8.2%) in greater numbers than experimental survey participants. Fewer experimental survey participants reported using a pharmacy to dispose of a medication (6.8%). Take-back event participation is likely influenced somewhat by the availability of other, more permanent disposal alternatives. The experimental survey drew from a national population, whereas ESP drew from New York State, where there are several counties with permanent drop-off opportunities. The experimental survey also drew from a population of people who have a health condition or who have some awareness of health conditions and who possibly have been exposed to more messages about safe drug disposal.

Take-back event attendees in Study 1 were fairly homogenous: older, more educated, and wealthier than average. Empire poll participants who reported disposing of a medication out-of-home were similarly older, more educated, and wealthier, though not to the extremes of the event participants. Participants reported little difficulty associated with attending the event. Event participants reported strong support for both environmental and public health issues associated with drug disposal; there were no singular issues that appeared to drive participation. Most event participants appeared to be committed to disposing of medication outside the home through some means. Few indicated that without the event they would have disposed in-home; most would have sought out another out-of-home disposal method or held on to the medications.

Based on findings from all three studies, there does appear to be an association between out-of-home disposal and age. Older adults are more likely to use take-back methods than dispose of unwanted medications at home, while younger adults tend to favor in-home methods. For both take-back event participants and Empire poll participants who reported having disposed out-of-home, participation among people ages 55+ was much higher than the percent of people that age in the county or the state. Among take-back event participants, the 45-54 age category was a bit larger than countywide (18.8% vs. 14.1%). For Empire participants reporting out-of-home disposal, the percentage in the 45-54 category was larger than statewide numbers (24.6% vs. 19.1%). Both studies suggested relatively little out-of-home disposal in the 18-24 age category.

It is possible that older adults have been the targets of more efforts to encourage drug take-back behavior and that these efforts have been successful in driving take-back participation. It is also possible that older adults have larger quantities of leftover drugs, which leads them to expend more effort to determine how to dispose of them safely. The middle-aged group (45-54) may be responsible for helping older relatives with health issues, and consequently may be handling more medications. In general, older adults may have more resources (e.g., time, access to transportation) and may find it easier to overcome barriers to out-of-home disposal participation.

Strengths and Limitations

Limitations

Threats to construct validity. For each of the three studies, there is a threat to construct validity from mono-method bias. Each of the studies relies on a survey for data collection. Ideally, future research would include additional methods (e.g., home observation of drug storage).

In addition, there is a threat to construct validity from mono-operation bias in instances where a construct is measured with one question. In some cases, there were multiple questions intended to measure the same construct (e.g., public health-related concerns), and an average from the responses were used. In other instances, such as familiarity with a location, there was only question. The number of questions was limited in some cases to keep survey length reasonable, and in the case of the ESP, was constrained by cost (ESP charges a per-question fee).

Self report poses a threat to construct validity, particularly in the ESP and experimental studies. Because participants in the take-back event were intercepted at the event, we can be certain that they actually participated in take-back behavior. ESP and experimental participants self-reported their past disposal behavior. For all three studies, answers regarding future intentions are hypothetical. Ideally research would be longitudinal and measure individuals' actual drug disposal behavior over time.

Evaluation apprehension also poses a threat to construct validity in each of the studies. It is possible participants answered questions in ways that they perceived to be socially desirable or "correct." For example, there was a tendency for people to state that they intended to dispose of medications out of the home in the future, though they had used in-home disposal most recently.

Finally, for the experimental study, it is possible that the operationalization of the independent variable (the scenarios) was not strong enough to elicit a response (i.e., it is possible the non-significant findings were due to poor operationalization of the construct).

Threats to internal validity. Poor operationalization of an independent variable (the scenarios in the experimental survey) also represents a threat to internal validity, as we are less certain that the findings are due to the intervention. Future research could test more in-depth messages or exposure to communications campaigns.

Aside from the scenarios in the experimental survey, no independent variables were manipulated in any of the studies. Any conclusions regarding relationships between variables are limited to correlation (i.e., no conclusions regarding causation can be made).

Threats to external validity. Each of the three studies is limited in terms of generalizability or external validity. The take-back event study focused on one event in one particular location. The Empire State Poll was based on a random sample of a much larger population, but is still limited because it focuses on residents of New York State.

There is a selection by treatment threat for the experimental survey. Experimental survey participants were randomly drawn from a large national databank, but they self-selected into that databank and their demographics did not mirror the U.S. population. Therefore, the results may apply to this specific group, but may not generalize to the larger population. It is possible that people in the databank differ from the general population, for example they may be more aware of medication-related issues.

Strengths. The current research used a variety of methods and engaged study participants from different populations to provide insights into drug disposal behavior. The Empire State poll covers the largest geographic area and population size in a random sample survey regarding drug disposal to date. The findings from the poll, including the percent of people who have disposed of a medication and the methods they used to dispose, are likely the most accurate figures available. The local event survey had a 94 percent participation rate and provided a thorough description of people who engage in take-back behavior. The experimental survey used a unique study design to explore factors that might influence drug disposal behavior.

Implications and Future Research

We live in a complex system where there are many influences on our behavior. Influences range from the individual level (e.g., attitudes and beliefs), to micro systems (e.g., facilities available in our neighborhood), to exo and macro systems (e.g., laws, broad health services, values) (Bronfenbrenner & Morris, 1998). For a behavior to occur, an individual needs to have the knowledge, interest, and motivation to act, and that individual's desire to act (or in some cases his or her habit) needs to be sufficiently strong enough to overcome barriers. In the case of drug disposal, an individual is faced with some level of inconvenience to safely dispose of drugs outside of the home. To change people's drug disposal behavior, an intervention can focus on one or more levels within the larger system.

The current research provides evidence that there is some general awareness regarding safe drug disposal and the "right" thing to do, and that there is an intention among some people to choose out-of-home method of drug disposal, yet out-of-home disposal rates are relatively low. The findings suggest that one potentially fruitful behavior change strategy would be to provide a more supportive environment, or to make out-of-home disposal more convenient. Most rules governing mandated take-back programs include some form of "convenience standard," or guidance on the availability of take-back sites (Product Stewardship Institute, 2017). Convenience is generally defined as a number of locations per a given number of residents or a number of sites in a given geographic area (e.g., a minimum of one site plus one additional site per 30,000 people). Findings from the take-back survey support Gray and Hagemeier's (2012) conclusion that geographical proximity is one important factor for siting permanent take-back locations, as event data showed most people traveled five miles or less.

Yet convenience is more than distance or density. One program administrator interviewed prior to the current research stated that with everyone in his region living within 10 miles of a drop box, drug disposal could not be more convenient. However, the drop boxes in his region were located in police stations. As the take-back event survey results showed, among people who are inclined to use a take-back method, pharmacies and local public waste facilities are preferred to and more familiar than police stations. Taking people's preferences into account and providing drop-off opportunities that fit with people's existing knowledge and routines could result in increased safe drug disposal behavior.

Future research could more deeply explore the reasons why people prefer certain locations to others, and findings could be used to make adjustments to where drop-off opportunities are available, or, if not possible, to make non-preferred locations more familiar and acceptable to people. Future research could also examine aspects of convenience more closely through direct intervention (i.e., a field experiment) or by studying a situation where environmental changes are being implemented (i.e., a natural experiment). Research could compare different take-back location configurations (e.g., setting type, hours, proximity to population) and associated take-back behavior.

In terms of the individual level, a lot of existing drug disposal awareness programs target older individuals, as they are more likely to have a prescription drug. However, as we have seen, most people, regardless of age, have experience with medication disposal. Broad awareness and education efforts may help to establish safe drug disposal behavior in younger generations who can continue that behavior across life stages and may reach middle-aged populations with caregiving responsibilities. The local event survey provided some descriptive information about who participates in drug take-back and why they chose take-back. However, given the relatively small sample size and the somewhat unusual characteristics of the local population (e.g., high education levels), the study revealed few differences among respondents that could be used to tailor information or marketing campaigns. Likewise, the experimental survey revealed no differences in response by age, gender, or income. Future research should look more specifically at how different groups respond to interventions, perhaps with more robust messages or marketing interventions, as noted above in the limitations section.

Finally, future research could include longitudinal studies to measure the impact of interventions over time. Research could also incorporate additional methods, such as home visits, observations, and interviews, to learn more about individual characteristics and drug disposal behavior.

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APPENDIX

Table A1: Demographic Characteristics of Online (Research Match) Survey Respondents

Variable	Study Participants	U.S.
Age category (18+)		
18-24	7.3%	12.1%
25-34	18.8%	18.0%
35-44	13.7%	16.2%
45-54	17.0%	16.8%
55-64	24.9%	16.7%
65+	18.2%	20.2%
Sex		
Female	80.5%	50.8%
Male	18.7%	49.2%
Other	0.8%	
Education		
Less than high school degree	0.4%	13%
High school degree	3.9%	27.5%
Some college, no degree	15.7%	21%
Associate degree	9.4%	8.2%
Bachelor's degree	22.5%	18.8%
Some Graduate education	9.4%	--
Graduate degree	38.7%	11.5%
Income, annual $		
<$20k	9.6%	17.2%
20-34.99k	10.8%	15.1%
35-49.99k	13.0%	13.2%
50-74.99k	19.0%	17.8%
75-99.99k	14.2%	12.2%
100 – 149.99k	18.5%	13.5%
150 – 199.99k	7.0%	5.4%
200k+	7.9%	5.7%

(U.S. Census Bureau, 2018a, 2018b)

CHAPTER 3

LAB FUME HOOD CLOSURE: A BEHAVIOR CHANGE EXPERIMENT

ABSTRACT

Fume hoods help ensure a safe working environment in laboratories by drawing potentially harmful air away from workers and expelling it out of the building through the ventilation system. Fume hoods consist of a flat workspace enclosed in a metal cabinet fronted by a moveable door (or "sash"). The door needs to be open when the fume hood is in use, but should be closed at all other times to provide safety, as well as to conserve energy. A single fume hood can use as much energy as three homes per year. This paper examines strategies to promote fume hood closure behavior. An experiment tested whether the addition of a closure signifier (a sticker) and the provision of comparative feedback would decrease the number of times fume hoods were left open while laboratory spaces were unoccupied or the hoods were likely inactive. The experiment included a control building where no fume hood intervention was implemented. In the experimental building, the combination of the sticker and feedback resulted in significantly fewer instances of hoods being left open (a 52.8% reduction overall). One year later, with the sticker still in place and no further feedback, the instances of hoods being left open were significantly lower than baseline in occupied spaces with inactive hoods. Findings suggest there are opportunities to improve the design of fume hoods to indicate proper closure behavior, as well as opportunities to use automated building data to provide laboratory workers with feedback to promote energy conservation.

INTRODUCTION

We each go about our daily lives engaging in routine behaviors with little awareness. Most of us consistently close refrigerator, microwave, garage, car, or front doors without consciously making a decision to do so. Such actions are examples of habits. In laboratory settings, there is one door that many people do *not* close consistently: the fume hood sash. Leaving a fume hood open when not actively in use results in a tremendous amount of wasted energy. The overall aim of the current research is to test whether a simple behavior change intervention can leverage our tendency toward non-conscious action and result in an increase in fume hood closure.

Laboratory Fume Hoods

Laboratory fume hoods are first and foremost safety equipment that protects workers by removing potentially harmful gasses from a building. A fume hood consists of a flat workspace enclosed in a large metal cabinet fronted by a moveable glass door, or sash (see Figure 1). A fume hood is equipped with a powerful fan that draws gasses and potentially harmful particulates away from lab technicians as they work, away from the front of the cabinet, and up and out of the building. The sash should be closed if no one is actively working at the fume hood. When a fume hood sash is left open, movement in the room (e.g., a person walking by) can alter airflow and cause dangerous fumes to escape from the hood.

Modern fume hoods typically use variable air volume (VAV) fans, which change speed depending on how far the sash is open. The further the sash is open, the harder the fan works to remove air. When the sash is closed, the fan still operates at a low level continuously (24/7), providing some airflow and preventing the buildup of fumes from any chemicals left in the hood.

Fume hoods use substantial amounts of energy, especially when left open. Because of their role in removing air from a building, laboratory fume hoods can be thought of as part of a building's heating, ventilation, and air conditioning (HVAC) system. HVAC systems in laboratory buildings use 100 percent outside air to ensure safety (Sahai, n.d.). Even with heat-recovery systems built into many modern HVAC systems, continuously changing over the air in a building uses a lot of energy. Depending on the number and type of hoods present, fume hoods can be a principal factor in a laboratory building energy use (Mathew, Sartor, Bell, & Drummond, 2007). Each fume hood is estimated to use the equivalent of three to three-and-a-half times the energy as an average U.S. home (Mills & Sartor, 2005). There are approximately 500,000 to 1,500,000 fume hoods in the U.S. costing more than $4 billion to operate (Mills & Sartor, 2005). The overall energy use associated with a VAV fume hood is determined largely by day-to-day habits of a building's occupants (specifically, whether or not the sash is closed when not in use) (Woolliams, Lloyd, & Spengler, 2005).

Figure 1: A Laboratory Fume Hood

Building Occupant Behavior and Energy Use

Fume hood energy use fits into a larger context of buildings and occupant behavior. In the U.S., approximately 41 percent of primary energy consumption is associated with buildings (U.S. Department of Energy, 2012), which makes buildings a frequent target for energy conservation efforts. At universities and other research institutions, laboratory buildings in particular are a focus of energy conservation efforts because of their high energy use stemming from HVAC requirements and other equipment use (Mathew et al., 2007; Woolliams et al., 2005). Laboratory buildings can consume four to five times as much energy than commercial buildings of similar size (Woolliams et al., 2005). However, there have been few studies regarding energy conservation opportunities and interventions in laboratory buildings (Kaplowitz, Thorp, Coleman, & Kwame Yeboah, 2012).

A lot of energy conservation efforts focus on technological fixes. The dominant model for whole-building sustainability currently is the LEED program (Leadership in Energy and Environmental Design) (U.S. Green Building Council, n.d.). LEED is a building rating and certification system used to guide the construction and renovation of buildings and building systems for energy conservation as well as for water conservation, healthy and sustainable materials, indoor air quality, and more. Typical energy conservation measures might include the installation of high efficiency HVAC equipment and lighting.

Unfortunately, many highly sophisticated green buildings are falling short on promised energy savings (Newsham, Mancini, & Birt, 2009; Yudelson & Meyer, 2013). The gap between *expected* and *actual* building performance can occur due to building design and maintenance problems, but they can also result from occupant behavior (Brown & Cole, 2009; Li, Hong, & Yan, 2014). Building occupants may use equipment in unintended ways, alter equipment, change equipment settings, block equipment, or otherwise act in a manner that increases energy use above what was predicted during the design process. Therefore, behavior is an important consideration for energy conservation efforts, including fume hood closure (Wesolowski et al., 2010).

Technological and behavior change interventions converge with the use of smart building technologies. Sensors that monitor occupancy and equipment use 24/7 can help pinpoint behaviors driving excess energy use. In the case of fume hoods, modern labs can be programmed to track instances of sashes being left open when the equipment is not in use. Such technology is particularly helpful when studying or attempting to change behaviors that are frequent and difficult to observe or measure reliably via self-report.

Automaticity and Habits

Our cognition and the behaviors stemming from cognition can be organized into two major categories: conscious and unconscious. Conscious processes are those that we actively control with awareness (Logan & Cowan, 1984). Making plans, weighing options, and making deliberate choices would fall under conscious cognition. Much of our day-to-day lives is governed by non-conscious processes (Bargh & Chartrand, 1999). We continuously think, act, and make decisions with no conscious awareness. Some non-conscious processes are simply instinctual, like the way we reach out and grasp an object. Other non-conscious processes have roots in conscious thought and action and then, through repeated exposures and action over time, become automatic (Bargh & Chartrand, 1999; Bargh & Ferguson, 2000; Graybiel, 2008). For example, learning to ride a bicycle takes conscious effort, but eventually the acts of pedaling, moderating speed, and stopping without falling over become automatic.

Non-conscious processes are important for our ability to function day-to-day because they conserve cognitive effort (Kahneman, 2011). If we are able to make decisions, interact socially, and behave automatically in environments and situations with which we are familiar, we are able to save highly valuable energy to deal with new, potentially dangerous environments and situations. Automaticity also allows us to conserve cognitive effort for decisions and behaviors that are consequential and allow other less important ones to become routine. Without non-conscious processes – including habits – it would be difficult for us to navigate our daily lives, where we make countless decisions and carry out numerous repeated behaviors (Neal, Wood, & Quinn, 2006). Automaticity, then is likely an adaptive function (Bargh & Chartrand, 1999).

Habits are a specially defined type of learned cognition or behavior characterized in part by automaticity. Habits are formed through repeated exposures to and experiences with a specific context or environment. Once formed in a specific environment, habits are then triggered by that environment. Once a habit forms, when a person encounters their environmental trigger, their response is a relatively fixed or rigid (Graybiel, 2008; Neal et al., 2006; Wood & Neal, 2009). For example, buckling a seat belt is an action we have to consciously learn initially, but then it becomes an unconscious habit over time with repetition in the same environment (i.e. our car). However, if the environment changes – if we climb into the back of a rideshare van with an unfamiliar seat belt configuration – then buckling a seat belt rises to a level of consciousness again.

The connection to the environment, particularly the physical environment, is an important aspect of habits. Cues from our environment can trigger unconscious judgments, emotions, and most importantly for the present research, behaviors (Bargh & Chartrand, 1999; Wood & Neal, 2009). As we become more familiar with and knowledgeable about an environment, we are less likely to make conscious evaluations and more likely to act automatically. Neurological activity settles into a pattern (Graybiel, 2008; James, 1890). Those patterns are then activated automatically each time we encounter the context (Neal et al., 2006; Ouellette & Wood, 1998). The combination of repetition, consistent connection to an environment, and our general tendency to conserve cognitive effort for unfamiliar, consequential situations can lead to the formation of habitual behaviors.

Habits are powerful in that they are both difficult to change and can be a stronger determinant of behavior than attitudes or intentions (Graybiel, 2008; Gregory & Leo, 2003; Ji & Wood, 2007; Klöckner, 2013; Neal et al., 2006; Ouellette & Wood, 1998). Relatively little is known about how to successfully initiate habit formation in the real world (Lally, van Jaarsveld, Potts, & Wardle, 2010). One likely leverage point for habit formation is the context itself (Neal et al., 2006; Verplanken, Walker, Davis, & Jurasek, 2008; Verplanken & Wood, 2006). Changing the context, or altering the environment can bring a person's conscious awareness to a situation. An alteration in the environment coupled with conscious awareness has the potential to disrupt a habit and perhaps create an opportunity for a different habit to form.

Because they are driven by non-conscious processes, habits are also difficult to measure. Research has relied on self-report (Sniehotta & Presseau, 2011; Verplanken, 2006; Verplanken & Orbell, 2003). Self-report by definition involves conscious thought, so there is a disconnect between the construct (habit) and the measure (the self-report habit index). People may be able to report a routine (a series of connected behaviors that include both conscious and unconscious thought), but may not be able to report specific habitual, unconscious aspects of that routine. For example, a person might be able to explain the order in which they complete major tasks in the morning (e.g., shower, comb hair, brush teeth), but would be unlikely to report the specifics of how they carried out those tasks (e.g., which leg they stepped into the shower with first, what part of their head they started combing first, which quadrant of their mouth they began brushing first). Thankfully because of the way human cognition works, we are free of having to make conscious decisions for each little step in a larger routine. But the lack of consciousness for small everyday behaviors also means those behaviors can be difficult to change, particularly without a change in the environment.

Environmental Affordances and Signifiers

When considering cues in an environment, two concepts from environmental psychology are particularly useful. First, environmental *affordances* connect to our perceptual system, our environment, and our actions. Most generally, an affordance is something in the environment – surfaces, layouts, objects, enclosures, and so on – that enables an action or behavior in a particular physical setting (Gibson, 1979). A flat surface affords sitting, a snow-covered hill affords sledding, a cleared path affords walking across terrain. Affordances can be thought of in negative terms as well – a vertical surface does *not* afford sitting, for example.

Objective affordances simply exist in the environment, but humans also alter their environment to create affordances, making an environment more or less suitable for particular actions. Affordances have thus become an important aspect in the design of objects, the built environment, and technology (Norman, 2013). Well-designed objects feature affordances whose corresponding action is easy to perceive correctly, without added information or instruction. For example, a well-designed door would be equipped with a flat panel at the appropriate height on the side that pushes in, and a pull handle on the side that opens out, without the need for signage indicating that one should push or pull the door.

Second, *signifiers* are perceivable cues or signals that provide information or suggest suitable behavior in particular situations or social settings (Norman, 2008). A signifier can be incidental or intentional. For example, a person who arrives to a train platform close to departure time can quickly determine whether the train has already left or has not yet arrived by looking at whether the platform is empty or is busy with people jostling for position. Painted lines on a street signify whether it is appropriate to pass other drivers. A well-worn path connecting two sidewalks (also an example of a physical trace) suggests where park-goers take shortcuts.

In the case of a laboratory fume hoods, a sliding track and a handle on a sash afford opening and closing. Signage and stickers could serve as intentional signifiers delivering cues for appropriate behavior (closing the hood). On the other hand, a sash left open by a lab-mate could be an unintentional signifier for a different type of acceptable behavior (leaving the hood open). Signifiers could be suggestive of norms, as they can provide evidence of others' behavior.

Feedback and Norms

Providing feedback on energy consumption has proven to be one effective strategy for reducing energy consumption. In a review of more than three dozen energy conservation experiments, households that received feedback on energy consumption reduced energy use 2.5 to 17 percent (Abrahamse, Steg, Vlek, & Rothengatter, 2005). Providing feedback on energy consumption appears to be more effective at influencing behavior than providing general information on energy conservation and appears to result in more lasting change than using rewards.

Delivering normative messages has also proven to be an effective strategy for increasing pro-environmental behavior, including energy conservation and litter avoidance (Allcott, 2011; Cialdini, Reno, & Kallgren, 1990; Stern, 2000). In a large randomized field experiment, providing comparative feedback that suggested normative energy usage succeeded in reducing household energy use by two percent (Allcott, 2011). In that experiment, researchers used illustrations (smiley faces) to provide customers with feedback on their household energy use relative to that their neighbors. Similarly, in an experiment with households that received feedback on energy consumption coupled with descriptive normative information (average household consumption in the neighborhood) or injunctive normative information (average household consumption plus an indication of whether the particular household was doing better or worse than average, provided in the form of a happy face or a sad face), providing descriptive normative information resulted in reduced energy consumption for those who were above average consumers, but increased energy consumption for those who were already consuming below average (Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007). Providing injunctive normative information resulted in reduced energy consumption for those who were above average consumers without the "boomerang effect" for those who were already doing relatively well.

Energy Conservation and Fume Hood Behavior in Laboratories

In a study of laboratories at a large university, Kaplowitz et al. (2012) found generally positive environmental attitudes toward energy conservation among principal investigators, lab staff, and students working in science laboratories. However, as with other areas of environmental behavior (Kollmuss & Agyeman, 2002), Kaplowitz et al. identified an attitude-behavior gap: despite positive attitudes, energy conservation was not a priority in the laboratories and often did not translate into action. Treatment of lab samples, uncompromised operations, convenience, and standardization of lab practices were all reported as being in conflict with energy conservation. In other words, for energy conservation behaviors to occur, they could not be seen as interfering with lab operations in any way. Factors important for choosing new equipment were reliability, quality, and cost (i.e., not energy efficiency). The conservation-related behaviors that study participants did engage in (e.g., equipment sharing, bulk operations, turning off lights) were done primarily for convenience and for monetary savings. While there were significant educational efforts at the university around environmental issues generally, participants noted that they lacked information specific to labs, including energy use and cost. A majority of participants lacked information about the impact of their behaviors (including closing the fume hood sash) on energy use. The biggest barriers had to do with operational constraints, specifically the importance of putting research first, and with safety. "It seems clear that the implementation of energy saving approaches must overcome perceptions that they compromise the ease and productivity of operations in the labs" (p. 587). The authors recommended closing knowledge gaps in part by providing regular feedback to lab users on their behavior and the impact of that behavior on energy use and cost.

A small number of universities have undertaken research on behavioral interventions specifically for fume hood closure. Intervention strategies include awareness-raising campaigns, information provision, the provision of feedback, competition and rewards, and the placement of stickers (Gilly & Michetti, n.d.; Irvine, n.d.; P. Mathew, 2012; Sahai, n.d.). For example, in one laboratory building with 25 labs and 200 fume hoods, approximately half of which were recorded as being left open overnight, researchers undertook an intervention that included a presentation and feedback to principal investigators who oversaw labs in the building (Wesolowski et al., 2010). Feedback was delivered monthly via email. Post-intervention, frequency of fume hood closure increased and average sash height during inactive periods decreased from nine percent open to six percent open.

With many behavioral interventions, particularly with awareness-raising campaigns that use competitions and rewards, persistence of effects over time is a challenge. Fume hood behavior is no different (U.S. Department of Energy, 2012). Few laboratory studies have measured effects over time. Feder, Robinson, and Wakefield (2012) implemented a multi-faceted campaign for fume hood closure and measured results immediately and several months later. The intervention consisted of various activities and tools to raise awareness, including a launch party, posters, a website, and stickers (in the shape of a ruler, with multiple thumbs up near the bottom, where the sash would be closed or nearly closed, and several thumbs down covering approximately two-thirds of the top portion of the ruler). The researchers also held a competition led by "sash patrols" who carried out surprise inspections and awarded stamps to labs where fume hoods were closed when unoccupied. Each stamp increased a lab's chances of winning a prize. Prior to the campaign, only 3.1 percent of hoods were closed when unoccupied. During the campaign, the figure rose to 61.3 percent. Eight months after the campaign, the compliance rate dropped significantly (to 14.5%), but not back to pre-campaign levels. The authors concluded that competitions and prizes (and the withdrawal of prizes) might reduce long-term effectiveness.

Two universities tested a large sash-position sticker in the shape of an arrow with a red zone in the upper levels of the sticker and a green zone in the lower levels (U.S. Department of Energy, 2012) (See Figure 2). In one case, researchers manually measured sash heights in 10 laboratories before sticker installation and then two months later and again several months after installation. In the second case, researchers recorded sash height from an automated building monitoring system in 51 labs during 10-day periods before installation and one, two, and three months after installation. Both universities found significant improvements in sash closure behavior. The behavior persisted over time, with some isolated exceptions that then became candidates for targeted outreach.

Figure 2: University of California System Fume Hood Sticker

Fume hood interventions have at times created confusion. Stickers placed on fume hood sashes often suggest a safe opening height (when a fume hood is actively in use, the sash should be kept at a height that protects the lab worker's face). The suggested safe level can be mistaken as the appropriate level to keep the sash at *all* times, rather than just when in use (U.S. Department of Energy, 2012). A wide range of acceptable heights can also send confusing messages in terms of normative behavior.

Gaps

Fume hood closure behavior has substantial implications for energy use. There are several gaps in the existing research, and more research is needed to identify a simple, low-cost, and effective intervention to alter behavior. First, most laboratory behavior interventions have been information-heavy and labor intensive (i.e., requiring frequent updates, written materials, meetings, etc.). Second, with custom combinations of events, presentations, information campaigns, and emails, existing interventions are difficult to replicate. Third, many studies have relied on manual spot checks for hood closure data, which introduce measurement issues. For example, one study reported that there were instances when lab workers warned each other that a patrol was on the way, which gave them time to close the hood (Feder et al., 2012). Fourth, while there have been studies using automated building data, the data did not account for occupancy. Average sash height, the typical dependent variable derived from building data, might simply reflect changes in activity levels (e.g., labs have become more or less busy), rather than instances when hoods are left open when no one is working. Finally, there have been no behavior change intervention experiments that included a control group.

Current Research and Hypotheses

Lab fume hood closure behavior corresponds well with the concept of habit. Closure is a simple behavior with no sub-steps, no need for significant learning to occur, no other behavior that needs to be undone or stopped, and the existing fume hood closure behaviors (or lack thereof) are not particularly strong (Verplanken & Wood, 2006). In addition, the context is stable and it is easy to tie the behavior to an environmental cue or signifier. Over time, closure behavior ideally should require no conscious cognitive effort on the part of lab workers, and no sustained effort on the part of lab or building managers to support the ongoing behavior. In the short term, establishing closure behavior as an unconscious habit might require briefly raising awareness.

Feedback, particularly feedback that suggests norms, is an effective behavior change strategy (Schultz, 2014), and also might be useful in bringing attention to the behavior. The following study was designed to test whether a simple, low-cost intervention will increase fume hood closure behavior. Specifically, the intervention includes a closure signifier (sticker) and comparative feedback.

Hypothesis 1: Installation of the sticker will be associated with a decrease in the number of times fume hoods are left open when the area is *occupied*.[6]

Hypothesis 2: The addition of feedback will further decrease the number of times fume hoods are left open when the fume hood area is *occupied*.

Hypothesis 3: Installation of the sticker will be associated with a decrease in the number of times fume hoods are left open when the area is *unoccupied* and the hood is likely inactive.

Hypothesis 4: The addition of feedback will further decrease the number of times fume hoods are left open when the fume hood area is *unoccupied* and the hood is likely inactive.

Hypothesis 5: Over the long term, the presence of the sticker alone will continue to be associated with a reduced number of times the fume hood is left open when the area is *occupied*.

Hypothesis 6: Over the long term, the presence of the sticker alone will continue to be associated with a reduced number of times the fume hood is left open when the area is *unoccupied*.

[6] A fume hood enters an "occupied" alarm state when the fume hood sash is open and the area occupied for greater than two hours, a length of time that suggests lab workers are engaged in bench or computer work, rather than actively engaged with the fume hood.

METHOD

Setting

The study took place on the campus of a large research university in two interdisciplinary science buildings. The two buildings house a mix of molecular biology, biomedical engineering, genetics, biotechnology, and nutrition labs. According to environmental health and safety and facilities staff, the two buildings are relatively similar in terms of the types of laboratory activities taking place in them (and the most similar on campus).

The experimental building has 45 fume hoods. Nine were removed from the study because they were vacant or hibernated, and one was removed because it was kept open 24/7 to provide extra ventilation in a room with an abundance of heat-producing equipment (n=35). The control building has 84 fume hoods. Three were removed from the study because they were vacant (n=81).

Students, faculty, and staff who may be exposed to chemicals while working are required to complete the university's Laboratory Safety program, which consists of about two hours of lecture and video instruction. [7] The training addresses fume hood safety, specifically the importance of closing the hoods to avoid air contamination and reduce the risk of fire.[8] People dealing with radioactive, potentially infectious, or other specific hazardous materials are required to complete additional training. Individual labs may, at their discretion, offer lab-specific training and/or address lab procedures during lab meetings. The amount and content of individual lab discussions varies widely, depending on the principal investigator and, if applicable, lab manager.

[7] Prior to the study, the author completed the university's laboratory safety training. When walking through labs, the researcher wore safety glasses and followed other guidelines regarding dress and procedures.

[8] In 2008, a UCLA researcher died as the result of burns suffered after chemicals ignited during an experiment in a fume hood. The case is used in laboratory safety training to stress the importance of safe lab practices.

Research Design

The study used a quasi-experimental design with a no-treatment control group and pre- and post-test. The experiment occurred from late March to early May. It included collecting baseline data, followed by data from a time period with stickers installed, and then a time period with feedback (in addition to the stickers, which remained in place) (see Table 1).

Fume hood data accumulated 24/7 for nearly eight weeks. Data collected during Spring Break (which occurred in April) and weekends were excluded from analysis. Data were equalized for day of the week and number of hours across time periods to create the most accurate comparisons. Each time period in the analyses consisted of two weeks.[9]

Table 1: Experimental Design

	Two-Week Measurement Period			
Building	**Period 1 Baseline**	**Period 2 Sticker**	**Period 3 Sticker+Feedback**	**Period 4 Follow-up**
Experimental	O*	X_1 (Sticker) O	X_2 (Sticker + Feedback) O	X_1 (Sticker) O
Control	O	O	O	O

*O indicates measurement; X indicates intervention.

To check whether there were any lasting effects from the intervention, baseline data were also compared to follow-up data collected for two weeks, one year later (in April 2018).

Intervention

The intervention consisted first of a sticker placed on fume hoods (see Figure 3). The sticker took the form of a smiley face, cut in half, with one half installed on the frame and one half installed on the glass of the sash. Closing the sash results in a complete smiley face, while leaving open leaves the sticker "broken."

[9] Models that included weekend days resulted in the same outcome. The weekday model enabled the data to be matched on day of the week and for equivalent total hours to be calculated cleanly, with a buffer around spring break.

Two weeks after the stickers were installed, feedback based on unoccupied closure data was posted throughout the experimental building. Feedback included an image for each fume hood in the building – a smiley face for fume hoods that were rarely left open unoccupied, a straight face for fume hoods sometimes left open unoccupied, and a surprised face for often open when unoccupied (see Figure 4). Feedback sheets also included a note stating "Good lab practices go hand in hand with good research," a note that one fume hood can use as much energy as three homes in a year, a statement emphasizing that fume hoods should be closed every time they are not actively in use, and a footnote regarding the source of the data (from the automated building system). One week after posting, the feedback was updated.

Figure 3: Fume Hood Sticker

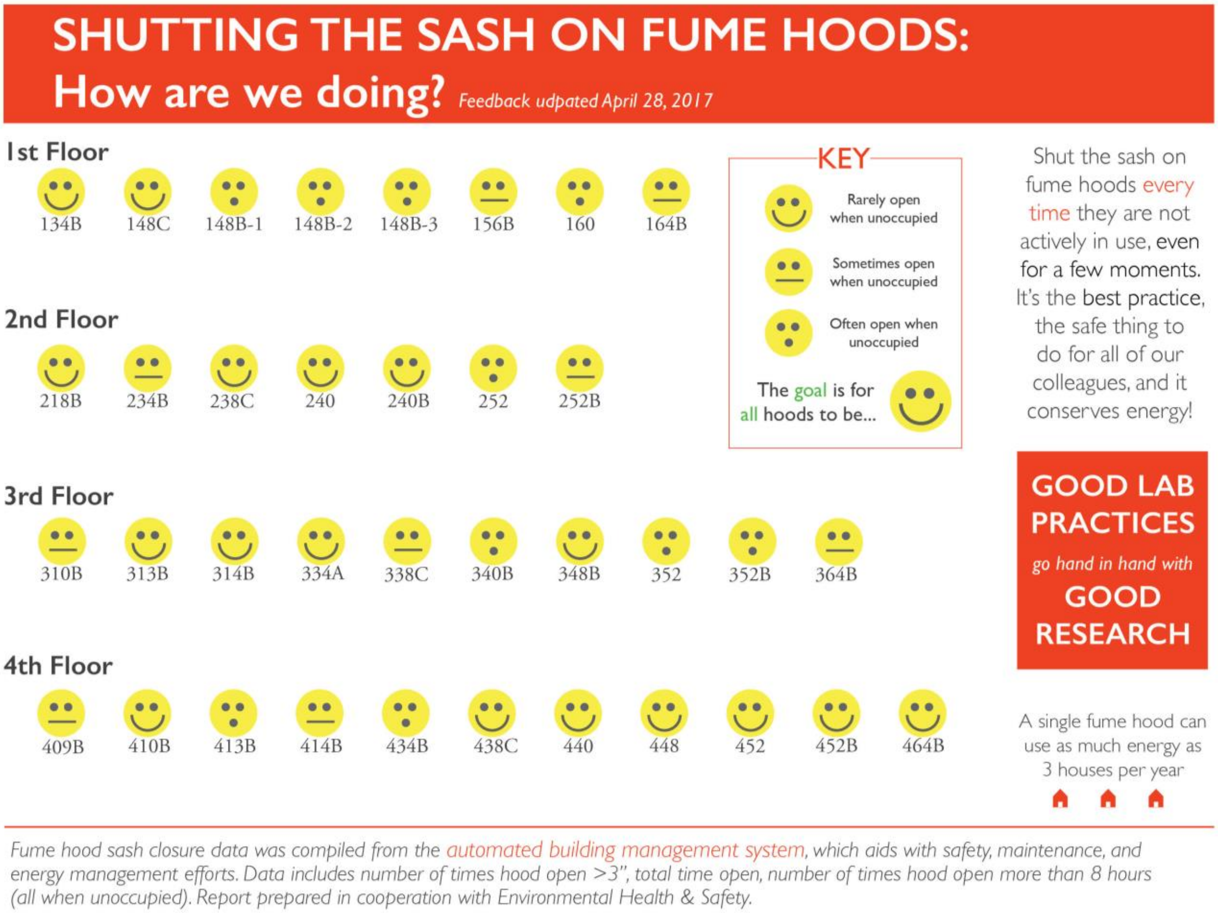

Figure 4: Sample Fume Hood Closure Feedback Report

Dependent Variables

The dependent variables for the study were (1) the number of times a hood was left open when occupied and (2) the number of times a hood was left open when unoccupied during a two-week time period (as shown above in Table 1). To yield the dependent variables, the building management systems in both the control and experimental buildings were reprogrammed to track fume hood status based on certain criteria. One criterion had to do with room occupancy, with two states (occupied and unoccupied). The other criterion was sash height. Three inches was used as an approximation for closure to allow for small structural issues (more than one sash was slightly off level with the hood frame and unable to close completely) and hoods where the number and size of hoses and power cords running under the sash made it impractical to achieve

100 percent closure. More specifically, the two dependent variables, which were also referred to as "alarm states" in the building management systems, were defined as follows:

- *Occupied alarm*: While an area was occupied and the fume hood sash was left open greater than 3" for greater than two hours (a length of time that suggested lab workers were engaged in bench or computer work nearby, rather than actively engaged with the fume hood).
- *Unoccupied alarm*: While the area was unoccupied for 15 or more minutes and the fume hood sash was left open greater than 3".

The building management systems logged hood closure and occupancy status for every 15-minute increment, 24 hours per day. The incidences of alarm states (times a hood was left open) were compiled and frequencies calculated for each hood.

Analytical Strategy

Data were analyzed using generalized estimating equation (GEE) models in SPSS for Mac (version 24). The models included data for each hood from each of the two buildings from all time periods (Period 1/Baseline, Period 2/Sticker, Period 3/Sticker+Feedback, Period 4/Follow-up). Data from one time period for a particular hood cannot be considered independent from data from a subsequent time period for that same hood. For example, in the experimental building, data from the Period 1 for a given hood is not independent from data from Period 2 for that same hood. GEE accounts for lack of independence among data points.

The dependent variable (the number of times a hood was left open in a given time period) ranged from zero to 84 and contained considerable variance relative to the mean. The model was specified with negative binomial distribution with log link, which is appropriate for models with count data with a lot of variability. The model was also specified with AR (autoregressive order) 1 working correlation matrix, which is applicable in situations with repeated measures over evenly spaced time intervals. Pairwise comparisons were used to test each hypothesis (i.e., to test for differences between each time period for each building).

RESULTS

Occupied Trends

During the Period 1/Baseline Period, hoods in the control building were left open while occupied an average of 9 times. Hoods in the experimental building were left open while occupied an average of 12.5 times (see Table 2 and Figure 4).

During Period 2/Sticker Period, the mean number of times hoods were left open in the control building dropped to 8.2 and in the experimental building dropped to 9.3. During the subsequent period when feedback was added (Period 3/Sticker+Feedback Period), the number of times hoods were left open in the control building rose to 11.3, while in the experimental building dropped to 5.9.

Table 2: Mean Number of Times Hoods Left Open While Area Occupied

TIME PERIOD	BUILDING	MEAN	STD ERROR	95% CONFIDENCE INTERVAL Lower	95% CONFIDENCE INTERVAL Upper
Period 1/Baseline	Control	9.0	1.7	6.28	12.90
	Experiment	12.5	2.9	7.96	19.68
Period 2/Sticker	Control	8.2	1.4	5.87	11.55
	Experiment	9.3	2.1	6.07	14.39
Period 3/ Sticker + Feedback	Control	11.3	1.6	8.46	14.99
	Experiment	5.9	1.3	3.83	9.04

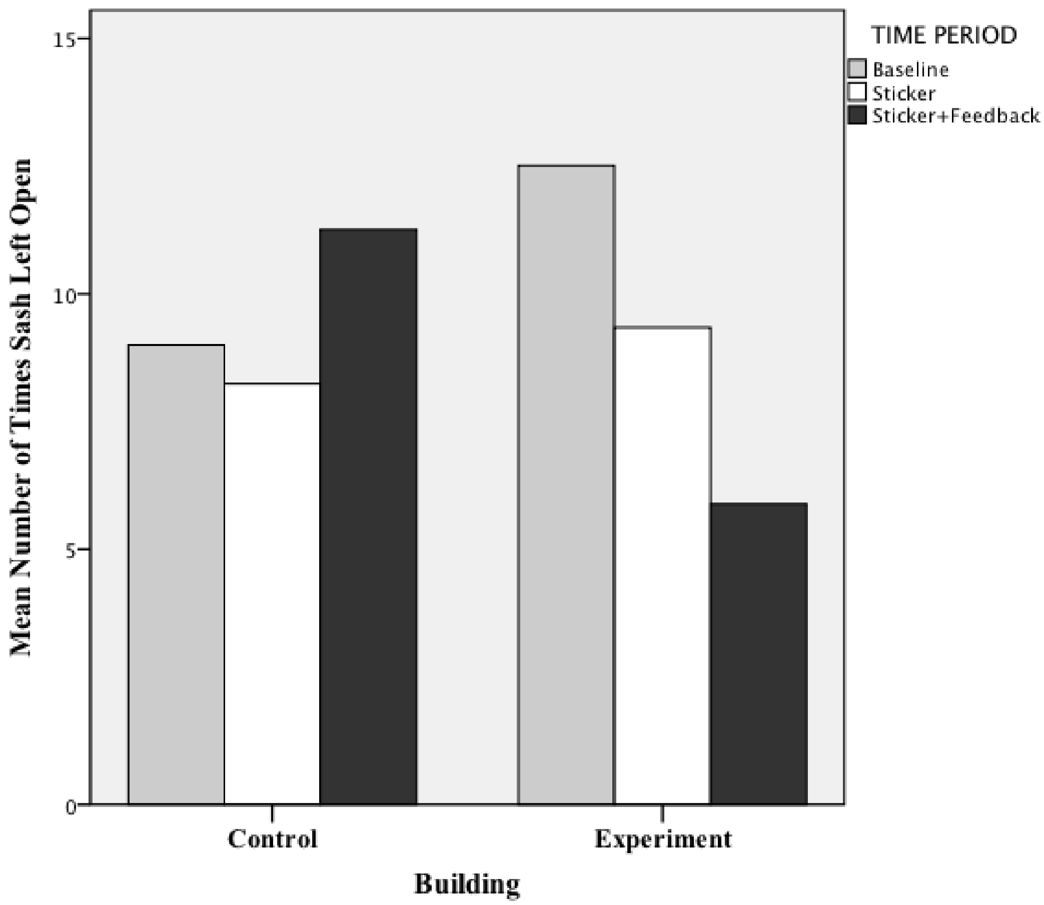

Figure 4: Mean Number of Times Hoods Left Open While Area Occupied

Unoccupied Trends

During the Period 1/Baseline Period, hoods in the control building were left open while unoccupied an average of 10 times. Hoods in the experimental building were left open while occupied an average of 22.1 times (see Table 3 and Figure 5). The control building mean was significantly lower than the experiment building mean at baseline.

During Period 2/Sticker Period, the mean number of times hoods were left open in the control building dropped to 9.7 and in the experimental building dropped to 17.9. During the subsequent period when feedback was added (Period 3/Sticker+Feedback Period), the number of times hoods were left open in the control building rose to 12.4, while in the experimental building dropped to 12.7.

Table 3: Mean Number of Times Hoods Left Open While Area Unoccupied

TIME PERIOD	BUILDING	MEAN	STD. ERROR	95% CONFIDENCE INTERVAL Lower	Upper
Period 1/Baseline	Control	10.0	2.0	6.70	14.93
	Experiment	22.1	4.2	15.17	32.06
Period 2/Sticker	Control	9.7	1.8	6.80	13.91
	Experiment	17.9	4.0	11.59	27.70
Period 3/ Sticker + Feedback	Control	12.4	2.0	9.11	16.93
	Experiment	12.7	2.8	8.25	19.60

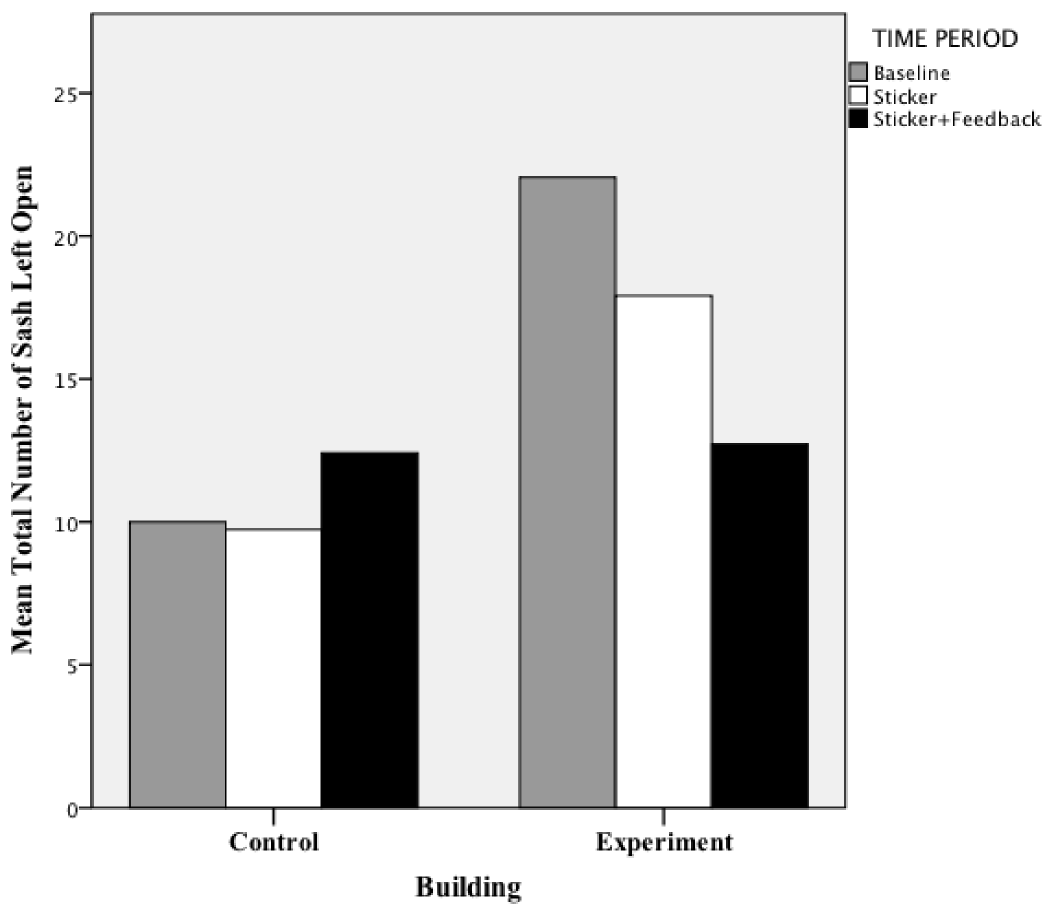

Figure 5: Mean Number of Times Hoods Left Open While Area Unoccupied

Experimental Effects

Overall, the intervention had a significant effect on closure in both occupied (Wald Chi-Square = 15.066, p=.001) and unoccupied (Wald Chi-Square = 18.229 p< .001) states (see Table 4).

Table 4: Overall Model Effects

	SOURCE	WALD CHI-SQUARE	DF	SIG (p)
Occupied	(Intercept)	339.505	1	0.000
	TIME PERIOD	4.253	2	0.119
	BUILDING	.072	1	0.788
	TIME PERIOD * BUILDING	15.066	2	0.001
Unoccupied	(Intercept)	415.037	1	0.000
	TIME PERIOD	2.448	2	0.294
	BUILDING	3.455	1	0.063
	TIME PERIOD * BUILDING	18.229	2	0.000

Table 5 shows specific pairwise comparisons for *occupied* time periods. Hypothesis 1 posited that installation of the sticker would be associated with a decrease in the number of times the fume hoods were left open when an area was occupied. There was no main effect of the sticker on closure activity (Period 1/Baseline Period compared to Period 2/Sticker Period in experimental building, p=.178).

Hypothesis 2 posited that the addition of feedback would further decrease the number of times the fume hoods were left open when an area was occupied. The model showed a significant effect with the addition of feedback (Period 2/Sticker Period compared to Period 3/Sticker+Feedback period in experimental building, p=.05 and Period 1/Baseline Period compared to Period 3/Sticker+Feedback period in experimental building, p=.012).

In the control building, there was no significant change from Period 1/Baseline Period to Period 2, when the sticker was in place in the experimental building (p=.291). The number of times fume hoods were left open in Periods 2 and 3 (when the sticker and then sticker+feedback interventions were in place in the experimental building) *increased* significantly (p=.039, .004).

Table 5: Pairwise Comparisons, Occupied

(I) TIME PERIOD* BUILDING	(J) TIME PERIOD* BUILDING		MEAN DIFFERENCE (I-J)	STD. ERROR	DF	SIG.	95% CI FOR DIFFFERENCE	
							Lower	Upper
Baseline * Experiment	Sticker * Experiment		3.2	2.4	1	.178	-1.44	7.78
Sticker * Experiment	Sticker+Feedback Experiment	*	3.5	1.8	1	.050	.01	6.91
Baseline * Experiment	Sticker+Feedback Experiment	*	6.6	2.6	1	.012	1.47	11.79
Baseline * Experiment	Baseline * Control		3.5	3.3	1	.291	-3.01	10.04
Baseline * Control	Sticker * Control		.8	1.0	1	.462	-1.27	2.80
Baseline * Control	Sticker+Feedback * Control		-2.3	1.1	1	.039	-4.41	-.11
Sticker * Control	Sticker+Feedback * Control		-3.0	1.0	1	.004	-5.07	-.98

Table 6 shows specific pairwise comparisons for *unoccupied* time periods. Hypothesis 3 posited that installation of the sticker would be associated with a decrease in the number of times the fume hoods were left open when an area was unoccupied. There was no main effect of the sticker on closure activity (Period 1/Baseline Period compared to Period 2/Sticker Period in experimental building, p=.224).

Hypothesis 4 posited that the addition of feedback would further decrease the number of times the fume hoods were left open when an area was occupied. The model showed a significant effect with the addition of feedback (Period 2/Sticker Period compared to Period 3/Sticker+Feedback Period in experimental building, p=.014 and Period 1/Baseline Period compared to Period 3/Sticker+Feedback Period in experimental building, p=.004).

In the control building, there was no significant change from the baseline period to the sticker period (p=.814). The number of times fume hoods were left open in the sticker and sticker+feedback periods *increased* (p=.052, .033).

Table 6: Pairwise Comparisons, Unoccupied

(I) TIME PERIOD* BUILDING	(J) TIME PERIOD* BUILDING	MEAN DIFFERENCE (I-J)	STD. ERROR	DF	SIG.	95% CI FOR DIFFFERENCE Lower	Upper
Baseline * Experiment	Sticker * Experiment	4.1	3.4	1	.224	-2.54	10.83
Sticker * Experiment	Sticker + Feedback * Experiment	5.2	2.1	1	.014	1.07	9.33
Baseline * Experiment	Sticker+Feedback * Experiment	9.3	3.2	1	.004	3.02	15.67
Baseline * Experiment	Baseline * Control	12.1	4.7	1	.010	2.88	21.23
Baseline * Control	Sticker * Control	.3	1.2	1	.814	-2.00	2.54
Baseline * Control	Sticker+Feedback * Control	-2.4	1.2	1	.052	-4.86	.02
Sticker * Control	Sticker+Feedback * Control	-2.7	1.3	1	.033	-5.17	-.22

Long-term Effects

Occupied trends

During the two-week follow-up period one year after the original experiment, hoods in the control building were left open while occupied an average of 9.9 times, similar to Period 1/Baseline Period (9.0). Hoods in the experimental building, where the sticker was still in place, were left open while occupied an average of 7.5 times, an increase from the Period 3/Sticker+Feedback period (5.9), but lower than both the Period 2/Sticker (9.3) and Period 1/Baseline (12.5) periods (see Table 7).

Unoccupied trends

During a follow-up period one year after the intervention, hoods in the control building were left open while occupied an average of 10 times, the same as Period 1/Baseline. Hoods in the experimental building were left open while occupied an average of 17.1 times, an increase from the Period 3/Sticker + Feedback period (12.7), slightly lower than the Period 2/Sticker period (17.9), and lower than the Baseline period (22.1) (see Table 7).

Table 7: Mean Number of Times Hoods Left Open, One Year Later

OCCUPANCY	TIME PERIOD	BUILDING	MEAN	STD. ERROR	95% CONFIDENCE INTERVAL Lower	Upper
Occupied	Period 4/ Follow-up	Control	9.9	1.5	7.31	13.36
		Experiment	7.5	2.5	3.94	14.24
Unoccupied	Period 4/ Follow-up	Control	10.0	1.8	7.03	14.33
		Experiment	17.1	4.2	10.56	27.56

Experimental Effects

Occupied. Hypothesis 5 posited that over the long term, the presence of the sticker would continue to be associated with a reduced number of times the fume hood is left open when the area is *occupied*. In the experimental building, there was a main effect of the sticker on closure activity, comparing the occupied Baseline Period to data one year later (mean difference = 5.0, SE 1.9, p=.008).

Unoccupied. Hypothesis 6 posited that over long term, the presence of the sticker will continue to be associated with a reduced number of times the fume hood is left open when the area is *unoccupied*. In the experimental building, there was no main effect of the sticker on closure activity, comparing the unoccupied Baseline Period to data one year later (mean difference = 5.0 SE = 3.6 p=.168).

DISCUSSION

The aim of the current study was to test whether a simple intervention could increase fume hood closure behavior. The study was designed to leverage a human tendency toward non-conscious action, using a permanent signifier to prompt a repeated behavior. The study also employed comparative feedback. Other than posted feedback, there was no communication to raise awareness regarding the fume hoods or energy conservation more generally. The study was the first to use automated building system data with occupancy status and an experimental control to study fume hood closure.

Overall, the intervention had a significant effect on closure behavior. In the occupied state, mean number of times hoods were left open dropped 25.6 percent in the experimental building during the sticker period, and 52.8 percent overall (from baseline through sticker plus feedback). In the control building, mean number of times hoods were left open dropped 8.9 percent during the initial period after baseline, and rose 25.6 percent overall. One year later, the mean number of times the hoods were left opened remained significantly lower than baseline.

In the unoccupied state, mean number of times hoods were left open dropped 19 percent in the experimental building during the sticker period, and 42.5 percent overall. In the control building, mean number of times hoods were left open dropped 3 percent during the sticker period, and rose 24 percent overall. One year later, the mean number of times hoods were left was approximately 20 percent lower than baseline, which was not a significant difference.

Results supported three of the six hypotheses. During the intervention periods, results did not support hypotheses stating that the installation of the sticker alone would result in a decrease in the number of times fume hoods were left open (when occupied or unoccupied), but did support hypotheses stating the addition of feedback would result in a decrease in the number of times fume hoods were left open. One year later, results suggest that the sticker alone was enough to continue to reduce the number of times fume hoods were left open, but only in the occupied state.

Although the mean number of times hoods were left open in the experimental building decreased after installation of the sticker, the change was not significant. It is possible that the sticker alone was not enough to elicit behavior change. Another possibility is that the sticker's effectiveness was delayed, or took longer than the two-week measurement period.

Habit formation does take time. Researchers from one study concluded that adopting a new eating, drinking, or physical activity habit can take anywhere from 18 to 254 days (Lally et al., 2010), not the 30 day window often promoted in popular culture. Acquiring automaticity for behaviors likely depends on the complexity of the behavior (i.e., the more complex the behavior, consisting of more steps, with a higher likelihood that some of those steps involve more conscious decision making and action, the longer it takes). Given the simplicity of the target behavior here, which consisted of only one step (the simplest behavior in the Lally et al. study, drinking a water at lunch each day, consisted of at least two steps), it would be reasonable to expect a relatively quick change. Still, the timeframe for behavior change may have been longer than the sticker-only period. It is also possible that it took time for workers to notice the sticker if they were not actively working at a fume hood in the first days of the study.

From the initial results, it can only be concluded that the sticker in combination with the feedback had an effect. There is evidence that feedback and social norms are effective in the context of energy conservation (see Schultz, 2014). It is also possible that the feedback simply served to bring attention to the sticker's function. A simple solution, like the sticker, might not work without something additional to bring it into conscious awareness or to suggest the importance of forming a new behavior.

Comparisons between baseline and activity one year after installation of the sticker show that when a fume hood area is occupied (presumably when the sticker is visible while workers are busy working at something other than the fume hood), the sticker continues to have an effect. However, when a fume hood area is unoccupied, there appears to be no effect. The results suggest that the intervention did not result in habit formation. When visible, it seems as though the sticker is an effective reminder to close the hood. But without an additional input to bring the closure problem to people's attention (such as feedback), the sticker does not appear to be enough to significantly increase closure behavior at all times. The sticker might prove more effective in a lab with an open layout design where fume hoods are very visible.

Straight comparison of results with similar studies is difficult, as this experiment used count data (emphasizing each act of closure) and accounted for occupancy, while most other studies used average sash height opening. Wesolowski et al. (2010) reported a decrease in average sash height from nine percent to six percent open, a 33 percent reduction. Two universities where stickers were implemented were achieved average sash height reductions of approximately 50 percent (U.S. Department of Energy, 2012). During a sash patrol campaign, Feder et al. (2012) achieved an unoccupied closure rate of 61.3 percent, a large improvement over the 3.1 percent closure rate prior to the experiment.

Limitations

Threats to internal validity

The study is limited by several threats to internal validity, or the confidence we can have that the intervention was the cause of the variance in the dependent variable. First, although the experimental and control buildings were matched as closely as possible in terms of the type of work being performed in them, the groups were non-equivalent. It is possible that work activities in two buildings varied at the time of the study, influencing amount of fume hood use, and posing a selection by history threat. However, there were no informational campaigns or known events taking place at the time of the study that would account for the observed effects.

Second, given that the experimental group began with a higher rate of leaving the fume hoods open, there is also a statistical regression to the mean threat to internal validity. However, in the case of occupied times, by the end of the experiment, the average number of times fume hoods were left open was higher in the control building than the experimental building (i.e., the two did more than converge). It would be very unusual for an experimental group to regress toward the mean so much that it would fall below the initially lower control group, so regression toward the mean is an unlikely alternative explanation for the results. In the case of unoccupied times, by the end of the experiment, the average number of times fume hoods were left open in the control building had increased and experimental building had decreased such that they almost, but did not quite converge. It is more difficult to rule out regression to the mean in this case, but is still an unlikely explanation, as the groups were not purposefully assigned to conditions based on pre-experiment data (the buildings were assigned to experiment or control conditions before baseline data was compiled). Overall, the patterns observed in the means during the course of the experiment suggest it is unlikely that regression to the mean was a driving factor behind the findings.

One option that had the potential to strengthen the study would have been to randomly assign individual hoods to control and experimental treatments. However, the possibility of diffusion of treatment within a building was another consideration that factored into the design. Because in some instances there was more than one hood in an alcove, it would not have been possible in every instance to install the stickers and feedback for some hoods out of sight of other hoods. Random assignment by hood would have posed a diffusion of treatment threat.

Threats to construct validity

In terms of operationalization of the study's constructs, there were two factors that could pose a threat to validity. First was the definition of "left open." Three inches was used to allow for the fact that some hoods are not physically able to close, and the level is visibly close to closed. The airflow at three inches and zero inches is the same, so there are no energy use implications from using three inches. The levels were used consistently across the two buildings.

Second, there are many complexities associated with time and occupancy. By simply walking around, lab users could trigger the occupancy sensor, creating the potential for a new alarm although no work had occurred at a hood in the intervening time. But fact remains that any time someone walks past an open hood, there was an opportunity for that person to close the hood. Also, hoods were not in in high traffic areas.

Threats to statistical validity

Another possible limitation of the experiment is low statistical power, given the modest sample size. A small sample size can lead to a Type II error, or a failure to detect an effect when one is present. The failure to find a significant difference in the sticker-only condition may be attributable to the experiment's modest sample size.

Threats to external validity

Finally, the study is limited because it used a convenience sample on one university campus, which limits its generalizability. There may be a setting by treatment effect and a selection by treatment effect, meaning the results found may only apply to this particular setting (a research university campus) and this particular group being studied (academics working in the life sciences). Likewise, there may be a history by treatment effect, meaning the results found are specific to this particular time period (e.g., when there is a general awareness about safety and energy conservation on university campuses).

Future Research and Design

Future research could address the study's limitations in a number of ways, for example, by increasing the sample size. The study was constrained by conditions in the field. An ideal setting would be one where there were enough fume hoods in discrete spaces to randomly assign individual hoods to experimental conditions. The ability to remove the sticker to isolate its effectiveness, or to randomly assign the order of feedback and sticker, as well as a longer experimentation time would also be useful in future studies.

An intervention that more closely approximates a physical design change, experimentation with different hood closure designs, or a comparative study of existing hood closure designs would also be useful. The prevailing thought in laboratory energy conservation and fume hood management has been that, "hood installations require a strong sash management plan that includes periodic training and awareness, informational placards, and possibly penalties and rewards for proper use" (Mathew et al., 2007). However, there is an important connection between the design of the hood and lab workers' behavior and the potential for a design change to lessen the need for a labor-intensive management plan has not been thoroughly explored.

Finally, automated building management systems open up new opportunities to provide building occupants with feedback and potentially effect change. Extracting data from a system that was not designed with behavior in mind is difficult. With some foresight, automated building management systems can be programmed to make it easy to extract data that can be used to provide feedback or to track behaviors, ultimately to reduce energy consumption in buildings.

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CHAPTER 4

DEVELOPMENT OF THE ENVIRONMENTAL BEHAVIOR SCALE FOR YOUNG ADULTS (EBS-YA)

ABSTRACT

Pro-environmental behavior is one important aspect of efforts to mitigate growing environmental problems. This paper presents a new valid and reliable scale specifically developed to measure young adults' pro-environmental behavior. A relevant pool of items for the scale was identified through interviews and focus groups with young adults who were outliers in terms of actively participating in sustainable behavior ("positive deviants"). A Rasch model was used to arrive at a final 32-item scale. Behaviors included in the scale relate to food, waste avoidance, waste sorting and management, energy conservation, and teaching others about pro-environmental behaviors, and were context-specific where appropriate. Test-retest reliability calculated using Pearson's product-moment correlation was 0.87 ($p<0.01$). In addition, Cronbach's Alpha was 0.90, reflecting strong internal consistency in the scale. Construct validity was evaluated in terms of item order, which was consistent with expectations regarding item difficulty based on interviews and focus groups. The scale was also assessed in terms of fit statistics, which indicated the scale measures a single underlying construct. The scale could be used to assess behavior change associated with sustainability-focused interventions and for longitudinal research (measuring behavior over the lifespan).

INTRODUCTION

With the global growth in population, environmental problems continue to worsen. Individual behavior choices are one factor driving environmental problems, which means that behavior change interventions are one important leverage point for mitigating problems. Young people are often the target of programs to promote pro-environmental behavior. It is important to understand not only whether such programs influence behavior in the immediate term, but also whether such interventions impact behavior later in life. The overall aim of this study is to develop a valid, reliable scale for young adult pro-environmental behavior that could be used to measure behavior at a point in time, as well as to measure change in behavior over time.

Literature

Pro-environmental behaviors (also described as environmentally sustainable behaviors, environmentally responsible behaviors, or environmentally significant behaviors) have been variously defined as actions that have fewer impacts than alternative actions (in terms of energy, materials, or impacts on the biosphere), actions intended to remediate environment problems, actions that contribute to conservation or preservation, actions chosen by someone who considers future consequences (Lee, Jan, & Yang, 2013), and actions that minimize harm to or even benefit the environment (Steg & Vlek, 2009; Stern, 2000). Pro-environmental behaviors include both one-time behaviors (e.g., purchasing an efficient car) and repeated behaviors (behaviors that occur regularly, either through habit or more conscious effort).

Measuring pro-environmental behavior

General pro-environmental behavior scales. The ability to measure pro-environmental behavior is important, whether for gauging the overall propensity of a population to engage in pro-environmental behaviors, assessing the change in such behavior over time, or evaluating the impact of an intervention to change behavior. Several general measures for pro-environmental behavior have been developed and validated.

The Maloney-Ward Ecology Inventory (Maloney & Ward, 1973) and a revised, shorter version (Maloney, Ward, & Braucht, 1975) were the earliest measurement scales to address pro-environmental behavior. Some statements in the scales relate to purchasing patterns (e.g., "I have switched products for ecological reasons"), while others reflect action at the neighborhood or community level (e.g., "I have never joined a cleanup drive") or political action (e.g., "I keep track of my congressman and senator's voting records on environment"). Not all of the items have a clear positive environmental impact associated with them (e.g., "I subscribe to ecological publications"). Environmental behavior questions were part of a sub-scale, with other sub-scales addressing how respondents feel about, verbal commitments to, and knowledge of ecological issues.

Recently developed general measures include the Pro-Environmental Behavior Scale (PEBS) (Markle, 2013) and a PEB scale that incorporates land stewardship (Larson, Stedman, Cooper, & Decker, 2015). Markle's PEBS scale was developed to address inconsistency in the literature (the author identified 42 unique behavioral scales at the time) and to incorporate items with clearer environmental impact. The scale includes 19-items on four dimensions (energy and water conservation, environmetnal citizenship, food, and transportation). Larson et al.'s study, which was developed with rural landowners and recreationists, was created to explore the multi-dimensionality of pro-environmental behavior, as well as to account for land conservation behaviors. Larson and colleagues (2015) created a 13-item scale and identified four dimensions: conservation lifestyle behaviors (e.g., household actions in the private sphere), social environmentalism (e.g., peer interactions and group membership), environmental citizenship (e.g., civic engagement in the policy arena), and land stewardship (e.g., support for wildlife and habitat conservation).

The General Ecological Behavior (GEB) scale (Kaiser, 1998; Kaiser, Doka, Hofstetter, & Ranney, 2003; Kaiser & Wilson, 2004) is one of the most commonly used measures. Different versions of the GEB contain 50-60 items that are answered on a yes/no or a never-to-always five-point scale (later coded dichotomously). The items relate to energy conservation, mobility and transportation, waste avoidance, recycling, consumption, and vicarious social behaviors toward conservation. The items vary in terms of difficulty and likelihood of occurring (e.g., purchasing solar panels vs. recycling paper).

The GEB was constructed as a Rasch model (see below for more explanation). Ecological behavior is particularly difficult to measure because it can be inconsistent (people with the same tendencies can act differently in a given situation, people with different tendencies can act the same in a given situation, and people who claim to be environmentally oriented can behave in pro-environmental ways in one domain and not in another). Inconsistency is driven by the fact that some pro-environmental behaviors are more difficult than others and that the behaviors are influenced by numerous social, cultural, and contextual (physical) factors. Inconsistency is essentially a feature of pro-environmental behavior. The Rasch approach is better suited to accommodate this inconsistency than other models: "A probabilistic Rasch scale…gives each participant more freedom to behave inconsistently, even across different behavior domains and even if those behaviors are different in difficulty" (Kaiser, 1998, p. 401). Kaiser and Wilson (2004) compared single- and multi-dimension (6 subscales) models, and found that the single dimension model was preferable. While the authors found a statistical difference between the two models, with the multi-dimensional model fitting the data better than the single-dimension model, the multi-dimensional model was only marginally better at predicting the data. They also found that most behaviors in the scale were highly correlated. They concluded that the difference between the two models was negligible (not of practical significance) and that pro-environmental behavior does not consist of clearly distinct or unrelated behaviors that warrant a multi-dimensional scale.

Evans, Haq, and Shapiro (2007), citing Kaiser's demonstration of the advantages of the Rasch model approach to pro-environmental behavior (specifically because it accommodates items that vary on a continuum of attitudes and difficulty), created an eight-item scale for young children. The items were developed with first and second grade children and target fairly simple behaviors (e.g., running water while brushing teeth, leaving the refrigerator door open while deciding what to eat).

Pro-environmental behavior measurement and context. Consistent patterns of behavior are often tied to particular settings or types of settings (Gifford, 2014). In the case of some pro-environmental behaviors, what is possible, as well as what is perceived as possible, often varies by location. For example, the availability of composting is limited in public places. A person might have a compost bin at home, but no compost option at work. Similarly, a college student who lives in a state with no recycling facilities but studies in a state with strict recycling laws likely varies behavior depending on where they are.

Perceived control contributes to a person's pro-environmental behavior as well. People's behavior is determined in part by their judgment of control over the situation (whether they can engage in the behavior and how difficult it will be) or judgment regarding whether their behavior will in fact make a difference (i.e., reduce environmental impacts) (Ajzen, 1991). Perceived control can vary with the behavior setting. For example, a person's perceived control over lighting and temperature at home might differ from that in an office setting. Similarly, a person's perceived control in a rented space might differ from that in an owned space.

Kaiser (1998) discusses behavioral inconsistency across pro-environmental behavior domains (e.g., recycling vs. transportation), and refers to social and cultural factors in making behaviors easier or harder to perform, but falls short of describing how the physical environmental context might account for some of this inconsistency. For example, Kaiser mentions that a woman might bike during the day but not at night because of fear of being harassed, but he does not address whether the city's design (e.g., the provision of bike lanes, lighting) facilitates nighttime biking. The Proenvironmental Behaviors Measure (Graves, Sarkis, & Zhu, 2013) is one measure that focuses on a particular setting for behaviors – the workplace. Items include specific actions (e.g., reducing energy use) as well as product development, knowledge sharing, idea generation, and other activities with particular applicability to a work setting. Lee, Jan, and Yang (2013) developed a measure tailored for community-based tourists. However, most scales measuring pro-environmental behavior are setting-agnostic. That is, they ask respondents to report their behavior in general, not in a particular setting, such as home, school, or work.

Impactful behaviors. Not all pro-environmental behaviors are equal in terms of their impact (see Kaiser et al., 2003). One line of thinking among researchers is that behavior change efforts should focus on the behaviors that are likely to have the most positive impact, for example in terms of mitigating climate change. Gardner & Stern (2008) identified a "short list" of such items. The items relate to driving (e.g., cutting highway speeds, combining errands), home management (e.g., buying a more efficient water heater, adding insulation, changing to more efficient light bulbs), and car purchase and maintenance (e.g., buying a fuel-efficient vehicle). The items are most applicable to homeowners and car owners. People who do not drive or are not in a position to upgrade their appliances and living quarters are limited to a small number of listed options, such as turning the heat down and washing clothes in cold water.

Issues and gaps. Existing pro-environmental behavior scales lack *relevance for young adults*. Most existing scales were developed for adults and emphasize energy conservation at home and car-related behaviors, which are typically under less control for young adults. A smaller number of scales were developed to measure young children's environmental behavior (Erdogan, Ok, & Marcinkowski, 2012; Evans et al., 2007; Larson, Green, & Castleberry, 2011). No scales target young adults who are semi-independent, or who have considerable control over their environment and purchases, but likely live in shared spaces, do not own a home, and may or may not have access to or control over a car. While the idea to focus on impactful behaviors, like adding home insulation, is an important one, many of the items that have been identified as most impactful are not relevant to young adults.

Most existing pro-environmental behavior scales *lack physical context*. When asked, "Do you compost?" the person with a compost system at home who is living in and working in a community with no composting facilities might be inclined to answer, "It depends." The person's non-composting behavior at work and in the community at large is a reflection of the context – of the physical availability of facilities – more so than the individual's propensity toward pro-environmental behavior. Faced with an always-to-never Likert scale, that person might choose the middle option. A more precise measurement instrument would specify context (i.e., do you compost at home?).

Rasch Models

Rasch analysis is a specific psychometric method for creating measurement instruments (Bond & Fox, 2015; Boone, 2016). Rasch scales are useful in situations where scale items have differing levels of difficulty and where the difference in difficulty among items is unequal. For example, Rasch models are prevalent in educational testing situations, such as those incorporating mathematical problems ranging from simple arithmetic to complex equations. The Rasch analysis takes into account both the ability of the person and the difficulty of an item, accounts for the unequal difficulties among items, and calculates the probability of a person answering an item "correctly."

Creating a Rasch model results in a "meter stick" for a construct (see Figure 1; adapted from Boone, 2016). Items and people are pegged to different locations, reflecting their respective difficulty or ability. A person's location relative to an item's location can be used to determine the probability that the person will answer that item "correctly," or with what might be expected. For example, in the figure below, Person A would have a 50 percent chance of answering Item 3 correctly, while likelihood of answering Items 1 and 2 correctly would be greater, and Item 4 less.

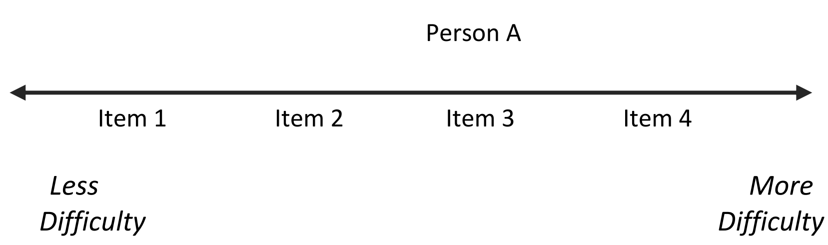

Figure 1: Rasch Measurement Representation

Note that item "difficulty" (and person "ability") is one way to describe what is being measured. Difficulty might not refer to actual complexity or objective knowledge required to complete an item, but might reflect perceived difficulty, familiarity, inconvenience, amount of effort required in a setting, availability, and so on. For example, the physical act of turning the lights off when one is the last person to leave a classroom is technically no more "difficult" than doing so when leaving a bedroom, but there might be uncertainty about whether turning the lights off is allowed in public places. On a Rasch scale for pro-environmental behavior, we would expect turning off bedroom lights and turning off classroom lights to be separated by some distance on the scale, with bedroom lights appearing on the less difficult side of the scale. Likewise, "ability" does not necessarily mean objective, physical ability to complete a task, but also incorporates a person's interest in and inclination toward completing the task. In developing a scale, researchers use knowledge of the construct to begin to create a range of items that vary in difficulty.

Positive deviance

Positive deviance refers to the idea that in any given setting there are usually a few individuals who "follow uncommon, beneficial practices and consequently experience better outcomes" than their peers (Marsh et al., 2004, p. 1177). Positive deviants are people who are successful in areas where others struggle or fail. While much social science research focuses on medians and averages, perhaps discarding outliers, the idea looking at positive deviance is to do the opposite – to examine outliers closely. With positive deviance, researchers study people precisely because their behavior is different.

Positive deviance as a concept has roots in the nutrition, where field researchers discovered they could learn from well-nourished people living in generally malnourished communities, and then disseminate successful practices for food storage and preparation (Wishik & van der Vynckt, 1976; Wray, 1972). Using qualitative methods, including interviews and observations, researchers study positive deviants' behavior to understand how they are able to achieve success. In addition to nutrition, interventions based on a positive deviance approach have been used successfully to improve child nutrition, newborn care, handwashing, hygienic food preparation, safe sex practices, and educational outcomes (Marsh et al., 2004).

To create a scale for young adults, one option would be to simply truncate an existing scale, such as GEB, by removing items that appear to be less relevant to young adults. However, by examining positive deviants' behavior, we can identify a broad range of possible behaviors, including uncommon behaviors or those not previously identified, which might entail the absence of a behavior or the avoidance of a purchase altogether. By learning more about what behaviors young adults actually do participate in, including perhaps behaviors that are not in adult behavior scales currently, we might learn about behaviors that could predict behavior later in life. Positive deviance research can be used to deconstruct behaviors to understand *how* behaviors occur, what behaviors are connected (e.g., what behavior may need to occur for another to be possible), and the structural context that behaviors occur in (i.e., what conditions exist in the physical environment that enable behaviors or make them easier).

Research Aims

The overall purpose of the current research is to develop a pro-environmental behavior scale for young adults. Specific aims include:

1. Develop a pool of pro-environmental behaviors, including those engaged in by "positive deviants";
2. Create a valid, reliable scale to measure pro-environmental behavior that is relevant to young adults and accounts for physical context.

METHOD

The steps for building an environmental scale for young adults consisted of item identification, which included data collection via interviews and focus groups; item development with pilot testing; and additional testing and model building to validate and check the reliability of the scale. The steps are described in more detail below. All participants were undergraduate and graduate students at a large university. The work was conducted with the approval of Cornell University's Institutional Review Board.

Item Identification and Exploration of Behaviors

Interviews

Participants and recruitment. Recruitment for interviews began via referrals from university staff to students who were known for being effective in terms of environmental behavior (e.g., students who hold volunteer positions that entail advising others on how to carry out environmental behaviors). Additional recruitment occurred via the university's research participant pool system and through study recruitment posters asking for people who "go above and beyond the norm" when it comes to sustainability, have "found ways to be more green at school" and like to discuss what they do to act sustainably. Participants were required to be students between 18 and 25 years of age and non-homeowners. Eligibility was confirmed through email upon response (although two interviews were truncated and discarded because the participants did not in fact meet the study criteria - one was a staff member and homeowner and the other admitted to doing no more than recycling). Participants were given a small incentive in the form of an Amazon gift card. A total of 15 useable interviews were conducted.

Interview protocol. Interviews were semi-structured. Each interview began with warm-up questions, including asking about the student's year, general routines, locations frequented on campus, and living arrangements. To thoroughly explore students' behaviors and uncover potential environmental behaviors that might be overlooked, each participant was asked to talk through a typical day and describe their actions upon waking, traveling to class, eating lunch, and so on. Each participant was then also prompted to consider behaviors that might fall into the following categories: energy, waste (minimization, sorting), water, transportation, and food. They were asked to think about behaviors that they avoided (e.g., abstaining from buying new items). Barriers were discussed, as well as attempted behaviors that were abandoned. Probing questions explored incentives, timing, frequency, perceived difficulty, location, and social aspects of behaviors. Interviews lasted 30-60 minutes and were audio recorded and transcribed.

Focus groups

As the interview process reached a point of saturation and identifying and recruiting individual positive deviants became more difficult, focus groups offered an additional way to recruit environmentally active students. The back-and-forth discussion format in focus groups also offered a new opportunity to prompt participants to recall behaviors they might have otherwise overlooked.

Participants and recruitment. Members of environmentally oriented campus clubs were asked to participate in the study. The clubs differed in interests, and no one participated in more than one focus group. Each club received a small honorarium for their participation. Three focus groups consisting of 4-8 people were conducted.

Focus group protocol. Focus groups were semi-structured (Krueger & Casey, 2009). Each began with an introductory question about how members discovered and joined their club. Transition questions focused on the environmentally sustainable behaviors students participated in when they first arrived on campus. Then students were asked to think about a typical day on campus and to discuss various behaviors by category (energy, waste, water, transportation food). Typical behaviors that came up during interviews, such as recycling, were mentioned as examples and participants were asked to discuss additional behaviors. Probing questions asked students to consider overlooked behaviors, barriers encountered, and behaviors attempted. Each focus group lasted approximately 75 minutes. Two note takers attended each focus group and the sessions were audio recorded. A detailed accounting of each focus group was created using the notes and recordings.

Item Development

Initial identification

Once all interviews and focus groups were complete and transcribed, two researchers reviewed the transcripts and interviewer notes and compiled a list of behaviors. After eliminating duplicates, a pool of 105 items remained.

Pilot testing

A scale with all of the items was created, with each item being preceded by the following statement: "We each have different habits. Think about what you do while living at school (your school 'home') as you read the following statements. For each statement, please indicate your level of agreement." The scale ranged from strongly agree (1) to strongly disagree (5), plus a "not applicable" option.

Using face-to-face intercepts, 20 participants completed the scale and were asked to discuss the clarity and meaning of the questions. Most feedback raised concerns regarding the response options (agree to disagree). Based on the pilot testing, the response options were changed to a 5-point never to always-never scale, items were reworded for clarity, and six items were eliminated.

The 99 revised items (see Table Appendix-1) were tested further with a group of students recruited using face-to-face intercepts at a variety of locations on campus. Ninety-two students agreed to participate and produced 89 usable surveys (three were incomplete).

Mean scores were calculated for each item and for each participant. Using students' overall scores, the top and bottom quartile of respondents was identified. Question-by-question, the responses of the top and bottom quartile of participants were then compared to consider how well each item distinguished between the most and least environmentally active participants. Generally, if the difference between an item's top and bottom quartile mean scores was less than one, the item was eliminated (Fishbein & Ajzen, 1975). Twenty-seven items were eliminated. Items were also checked to see if the mean responses were the reverse of what would be expected (i.e., the lower quartile's mean was higher than the highest quartile's mean). One item related to flying was reversed (the difference was close to zero) and was eliminated. The resulting pool was 71 items (see Table Appendix-2).

With the revised 71-item scale, another group of participants was recruited via face-to-face intercept at different locations on campus. A total of 189 students participated in this additional round of testing.

Mean scores and frequencies were calculated for each item. Ten items with many "not applicable" responses (ranging from 8-33%) were removed. Most inapplicable items had to do with cars. Other items related to heat and weatherization (16 and 33 not applicable responses), public computers (12 not applicable responses), cleaning products (13 not applicable responses), and cooking (30 not applicable responses). Seven additional items were eliminated because their wording differed in style from other items and they appeared duplicative.

Rasch Model Development

Using WinSteps 4.0.1, a Rasch model was created with the remaining 54 items (see Table Appendix-3). Rasch model development steps included examining item order, person-measure correlation, and item distribution (Boone, 2016; Linacre, 2012a).

Item order

When looking at the model, the first question is whether the items are ordered as would be expected, which speaks to construct validity (Boone, 2016). Measure order should appear logically consistent with what is known about item difficulty, frequency, and commitment needed to complete a behavior.

With the current scale, the expectation would be that turning off lights, recycling on campus, and using reusable shopping bags would be on the "easier" end of the scale, while policy work, nature preservation, and eating vegan would be on the more "difficult" end. In the initial Rasch model, working to change policy was at one end of the scale, while shutting lights off in private living spaces was at the other (see Table 1).

Table 1: Item Order and Person-Measure Correlation, Initial Model

Item Number	Total Score	Total Count	Model		Infit		Outfit		Person-Measure		Exact Match		Item (easiest to most difficult)
			Measure	S.E.	MNSQ	ZSTD	MNSQ	ZSTD	Corr.	Expected	Obsv'd %	Expected %	
34	289	169	1.55	.10	1.15	1.2	1.17	1.3	.40	.42	39.1	46.8	In private spaces where I live (like my bedroom), I turn off the lights when I leave the room
4	316	169	1.29	.09	1.26	2.2	1.19	1.6	.39	.44	43.8	42.4	In shared spaces where I live (like the kitchen), I turn off the lights if I'm the last person to leave the room
22	319	169	1.27	.09	1.14	1.2	1.04	.4	.60	.44	43.8	42.2	I recycle where I live
36	327	169	1.20	.09	.81	-1.8	.76	-2.2	.59	.45	52.7	41.4	I recycle on campus
39	327	169	1.20	.09	1.91	6.6	1.76	5.5	.47	.45	22.5	41.4	I take a refillable water bottle to school
2	338	169	1.11	.09	1.41	3.4	1.42	3.4	.23	.46	39.1	39.8	For short trips, I choose walking or biking over other methods of transportation
41	360	169	.94	.09	1.13	1.2	1.22	2.0	.29	.47	36.1	38.7	Where I live, I use daylight rather than turn on lights when possible
54	383	169	.78	.08	.93	-.6	.98	-.2	.49	.48	39.1	37.9	I use up leftovers
45	399	169	.67	.08	.85	-1.6	.86	-1.4	.48	.48	42.0	37.1	I reuse school or office supplies rather than purchase new
25	405	169	.63	.08	.81	-2.0	.84	-1.7	.46	.48	46.2	37.1	I take steps to make my things last longer
51	411	169	.59	.08	1.23	2.2	1.19	1.8	.53	.49	26.0	37.1	I use reusable shopping bags

1	417	169	.55	.08	.73	-3.0	.71	-3.1	.49	.49	45.0	37.1	I reuse containers
52	425	169	.50	.08	.68	-3.6	.68	-3.6	.66	.49	42.0	37.0	I go out of my way to recycle
20	437	169	.42	.08	1.16	1.6	1.23	2.2	.36	.49	33.1	36.8	I limit the amount I print
31	457	169	.30	.08	1.29	2.8	1.29	2.7	.46	.49	26.0	36.8	In public spaces, such as a bathroom or classroom, I turn off the lights if I'm the last person to leave
28	465	169	.25	.08	.51	-6.2	.51	-6.1	.68	.49	55.6	36.7	I choose recyclable products
16	471	169	.21	.08	1.47	4.3	1.49	4.4	.33	.49	26.6	36.6	I unplug electronics when they're fully charged
37	471	169	.21	.08	2.10	8.7	2.11	8.7	.35	.49	16.0	36.6	I take a reusable mug to school
50	476	169	.18	.08	.75	-2.8	.74	-2.9	.59	.50	40.8	36.6	I avoid buying products that won't last long
53	476	169	.18	.08	.72	-3.2	.74	-2.9	.47	.50	38.5	36.6	I borrow rather than buy products that I don't use regularly
27	483	169	.14	.08	.89	-1.2	.90	-1.0	.48	.50	45.0	36.6	I use energy saving settings on electronics
6	491	169	.09	.08	.67	-3.9	.68	-3.7	.56	.50	47.9	36.5	I inform myself on environmental issues for personal reasons (not for school or work)
32	491	169	.09	.08	.94	-.5	.94	-.6	.45	.50	42.6	36.5	When I choose fruits and vegetables, I choose in-season
35	492	169	.09	.08	1.08	.8	1.10	1.0	.49	.50	28.4	36.5	I unplug small appliances when not in use
29	503	169	.02	.08	.67	-3.9	.67	-3.8	.61	.49	44.4	36.5	I choose products made with natural ingredients

42	512	169	-.03	.08	.87	-1.4	.87	-1.4	.46	.49	38.5	36.4	I choose organic foods when available
40	517	169	-.06	.08	1.27	2.6	1.26	2.5	.47	.49	30.8	36.3	When I buy food for home, I plan with the goal of minimizing food waste
24	525	169	-.11	.08	1.44	4.1	1.46	4.2	.48	.49	25.4	36.6	I eat meatless meals
43	526	169	-.12	.08	1.10	1.1	1.14	1.4	.38	.49	34.3	36.6	I get through the week without throwing out any food
38	530	169	-.14	.08	.77	-2.6	.77	-2.5	.60	.49	42.6	36.6	I choose the least processed foods possible
5	531	169	-.15	.08	.70	-3.4	.71	-3.2	.50	.49	51.5	36.6	I actively work to preserve nature or natural spaces
33	532	169	-.15	.08	.90	-1.1	.89	-1.2	.46	.49	37.9	36.6	When I walk past litter, I pick it up
23	535	169	-.17	.08	.80	-2.2	.80	-2.2	.59	.49	42.6	36.6	When I buy a product with packaging, I choose one with recyclable (or compostable) packaging
47	540	169	-.20	.08	1.28	2.7	1.27	2.6	.52	.49	27.2	36.5	I compost on campus
17	548	169	-.25	.08	.56	-5.4	.57	-5.2	.57	.49	46.2	36.5	When I buy food, I choose local foods
19	548	169	-.25	.08	.68	-3.8	.67	-3.8	.58	.49	46.7	36.5	I avoid disposable or single-use products
46	553	169	-.28	.08	.62	-4.5	.64	-4.3	.59	.49	50.3	36.4	I make changes to my surroundings to make it easier for me to behave more sustainably
8	561	169	-.33	.08	1.30	2.9	1.32	3.0	.37	.49	29.0	36.4	When I shower, I limit my time to few minutes or less

18	572	169	-.39	.08	.82	-1.9	.81	-2.0	.60	.48	40.2	36.5	I help others recycle or compost correctly
21	583	169	-.46	.08	.49	-6.4	.50	-6.3	.64	.48	56.8	36.8	I choose biodegradable products
48	589	169	-.50	.08	1.93	7.6	1.92	7.4	.25	.48	18.9	36.8	I take reusable utensils to school
3	593	169	-.52	.08	.99	-.1	1.00	.1	.36	.48	42.6	36.8	If I buy something with packaging, I reuse the packaging
14	594	169	-.53	.08	.55	-5.4	.56	-5.3	.65	.48	52.1	36.8	I choose products with minimal packaging
49	596	169	-.54	.08	1.18	1.7	1.21	2.0	.43	.48	30.8	36.8	When my clothes wear out, I repurpose them
7	621	169	-.70	.08	1.11	1.1	1.07	.7	.48	.46	39.1	37.3	I go out of my way to compost
13	627	169	-.74	.08	.65	-4.0	.65	-3.9	.53	.46	48.5	37.3	I buy food directly from farms (through a farm share or at a farmers' market)
44	634	169	-.79	.08	.85	-1.5	.83	-1.7	.58	.46	44.4	37.7	I teach others specific behaviors to reduce their environmental impact
9	635	169	-.80	.08	.86	-1.4	.92	-.8	.63	.46	47.3	37.7	I choose foods that have the least environmental impact
10	638	169	-.82	.08	.79	-2.3	.76	-2.5	.51	.46	44.4	37.9	I teach others about environmental issues
12	639	169	-.82	.08	1.37	3.3	1.39	3.4	.27	.46	27.2	37.9	I choose to buy used clothes over new
26	646	169	-.87	.08	1.62	5.2	1.51	4.2	.41	.45	27.8	38.1	I compost where I live
30	665	169	-1.01	.09	1.16	1.5	1.19	1.7	.47	.44	33.7	38.3	I eat vegan meals
15	688	169	-1.18	.09	.94	-.5	.97	-.2	.38	.42	47.3	39.8	I minimize my use of electronics

11	733	169	-1.59	.10	1.13	1.1	1.14	1.1	.33	.38	47.3	47.8	I actively work to change policy to protect the environment (government, school, or other organizational policy)
Mean	508.1	169.0	.00	.08	1.02	-.21	1.02	-.2			39.1	37.8	
P. SD	104.2	.0	.68	.01	.36	3.4	.35	3.3			9.4	2.4	

Person-measure correlation

Person-measure correlation shows whether responses to each item correlate with the patterns of individual participants. Higher person measures (people who participate in more environmental behaviors) should correlate with more difficult items. No correlations should be negative.

When evaluating person-measure correlations for pro-environmental behaviors, a sizable range would be expected, people may specialize or have specific passions. So for example, a person who is passionate about avoiding meat might find it "easier" to complete the most demanding food-related behavior than to complete a relatively simple energy behavior. Specialization could result in lower correlations than one would expect for a series of items that were truly skills-based and varied only on objective difficulty. Correlations ranged from 0.23 to 0.68 (see Table 1). No correlations were negative. (Note that some of the lower-correlation items were eliminated during the Wright Map step, below.)

Item distribution

Finally, the Wright map provides a visual illustration of the items and their distance from one another in terms of difficulty. When multiple items appear together on a Wright map, it means the items are similar in terms of difficulty (Boone, 2016). Removing items could reduce the length of the scale without losing much information.

The Wright map revealed several instances of item clustering (see Figure 2; where items are shown on the right side of the figure). Items were evaluated in each cluster through an iterative process based on which of the item(s) had the lowest person-measure correlation and which items, overall, would result in a scale with a variety of behaviors. Some clustering was retained if the items reflected different types of behaviors. In other words, if four behaviors were clustered together, if two related to food, one of the food-related items would be eliminated. An additional 20 items were removed.

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Figure 2: Wright Map, Initial Model

RESULTS

Items

The measure resulting from the process described above consists of 32 items (see Table 2). Items address waste avoidance (9 items), waste sorting or management (3 items), small energy conservation steps (7 items), active teaching/doing (5 items) and food (8 items).

Model

Item order

Items appear to be logically ordered. Recycling and turning off lights are relatively easy. Eating vegan and actively working to change policy are relatively difficult, as is minimizing the use of electronics.

Person-measure correlation

Person-measure correlations ranged from 0.33 to 0.69 (see Table 2). The two lowest items were *I actively work to change policy*, which is an uncommon behavior that requires significant commitment, and *using daylight rather than turning on lights*, which might not be possible (due to constraints in the physical environment) for people who are otherwise engaging in pro-environmental behaviors. There were no negative correlations.

Item distribution

The Wright map with 32 items (see Figure 3) is much improved over the 54-item model (see Figure 2). There is a small amount of clustering in the map, suggesting some additional items could be eliminated to shorten the measure without degrading it (Boone, 2016). However, the topics of the items that appear together are dissimilar (e.g., buying in-season fruits & vegetables and unplugging electronics), so they were retained.

Table 2: Item Order and Person-Measure Correlation, 32-Item Model

Item Number	Total Score	Total Count	Model Measure	Model S.E.	Infit MNSQ	Infit ZSTD	Outfit MNSQ	Outfit ZSTD	Person-Measure Corr.	Person-Measure Expect-ed	Exact Match Obsv'd %	Exact Match Expect-ed %	Item (easiest to most difficult)
20	289	169	1.52	.10	1.17	1.4	1.22	1.6	.41	.46	39.6	48.0	In private spaces where I live (like my bedroom), I turn off the lights when I leave the room
2	316	169	1.26	.10	1.32	2.7	1.24	2.0	.39	.48	42.6	44.0	In shared spaces where I live (like the kitchen), I turn off the lights if I'm the last person to leave the room
13	319	169	1.23	.09	1.15	1.4	1.05	.5	.61	.48	45.6	43.4	I recycle where I live
22	327	169	1.16	.09	.80	-2.0	.74	-2.5	.61	.49	56.8	42.6	I recycle on campus
23	327	169	1.16	.09	1.93	6.8	1.77	5.6	.50	.49	27.2	42.6	I take a refillable water bottle to school
25	360	169	.89	.09	1.15	1.4	1.30	2.6	.33	.51	38.5	40.0	Where I live, I use daylight rather than turn on lights when possible
32	383	169	.72	.09	.99	.0	1.05	.5	.49	.52	39.1	39.0	I use up leftovers
28	399	169	.60	.08	.88	-1.2	.90	-1.0	.49	.52	43.8	38.3	I reuse school or office supplies rather than purchase new
30	411	169	.52	.08	1.30	2.7	1.25	2.4	.54	.52	27.8	38.1	I use reusable shopping bags
1	417	169	.48	.08	.82	-1.9	.82	-1.9	.46	.52	45.0	37.7	I reuse containers

18	457	169	.21	.08	1.39	3.6	1.38	3.4	.46	.53	23.7	38.1	In public spaces, such as a bathroom or classroom, I turn off the lights if I'm the last person to leave
16	465	169	.16	.08	.54	-5.5	.55	-5.5	.69	.53	57.4	38.4	I choose recyclable products
31	476	169	.09	.08	.81	-2.0	.83	-1.8	.46	.53	42.6	38.5	I borrow rather than buy products that I don't use regularly
15	483	169	.04	.08	.94	-.6	.95	-.5	.50	.53	43.2	38.5	I use energy saving settings on electronics
4	491	169	-.01	.08	.71	-3.3	.73	-3.0	.57	.53	46.7	38.6	I inform myself on environmental issues for personal reasons (not for school or work)
19	491	169	-.01	.08	1.04	.4	1.04	.4	.45	.53	42.6	38.6	When I choose fruits and vegetables, I choose in-season
21	492	169	-.02	.08	1.15	1.5	1.16	1.6	.50	.53	25.4	38.6	I unplug small appliances when not in use
26	512	169	-.15	.08	.92	-.8	.92	-.8	.48	.53	37.3	38.6	I choose organic foods when available
24	517	169	-.18	.08	1.34	3.2	1.34	3.2	.49	.53	33.1	38.6	When I buy food for home, I plan with the goal of minimizing food waste
14	525	169	-.23	.08	1.52	4.6	1.54	4.8	.50	.52	27.2	38.6	I eat meatless meals
3	531	169	-.27	.08	.77	-2.4	.80	-2.1	.50	.52	47.3	38.5	I actively work to preserve nature or natural spaces
29	540	169	-.33	.08	1.37	3.4	1.36	3.3	.53	.52	26.0	38.5	I compost on campus

9	548	169	-.38	.08	.57	-5.2	.58	-4.9	.61	.52	48.5	38.6	When I buy food, I choose local foods
11	548	169	-.38	.08	.73	-3.0	.72	-3.2	.59	.52	49.1	38.6	I avoid disposable or single-use products
10	572	169	-.54	.08	.83	-1.7	.82	-1.9	.64	.51	42.6	38.5	I help others recycle or compost correctly
12	583	169	-.61	.08	.55	-5.4	.56	-5.2	.63	.51	55.6	38.4	I choose biodegradable products
7	594	169	-.68	.08	.62	-4.3	.62	-4.3	.63	.51	52.1	38.8	I choose products with minimal packaging
6	627	169	-.91	.08	.68	-3.5	.69	-3.3	.54	.49	50.3	39.7	I buy food directly from farms (through a farm share or at a farmers' market)
27	634	169	-.97	.09	.89	-1.1	.86	-1.3	.60	.49	42.0	39.8	I teach others specific behaviors to reduce their environmental impact
17	665	169	-1.20	.09	1.19	1.7	1.22	1.9	.50	.47	36.1	40.7	I eat vegan meals
8	688	169	-1.39	.09	1.01	.2	1.04	.4	.39	.45	48.5	41.9	I minimize my use of electronics
5	733	169	-1.82	.10	1.19	1.6	1.23	1.7	.33	.41	47.9	48.9	I actively work to change policy to protect the environment (government, school, or other organizational policy)
MEAN	491.2	169.0	.00	.09	1.01	-.2	1.01	-.2			41.6	40.0	
P. SD	113.3	.0	.80	.01	.31	3.0	.3	2.9			9.2	2.7	

```
MEASURE                                   |                                    MEASURE
  <more> --------------------- PERSON  -+- ITEM    ----------------- <rare>
    2                                X  +                                         2
                                     X  |
                                        |
                                     X  |T X
                                        |
                                   XXX  |  XX
                                    XX T|  XX
    1                              XXX  +                                         1
                                  XXXX  |S X
                                   XXX  |  X
                              XXXXXXXX S|  XX
                        XXXXXXXXXXXXXX  |  X
                            XXXXXXXXXX  |
                        XXXXXXXXXXXXXX  |  XXX
    0                  XXXXXXXXXXXXXXX  +M XXXX                                   0
                   XXXXXXXXXXXXXXXXXXX M|  XX
                        XXXXXXXXXXXXXX  |  XXX
                          XXXXXXXXXXXX  |  XX
                             XXXXXXXXX  |  XX
                            XXXXXXXXXX S|  X
                             XXXXXXXXX  |S X
   -1                             XXXX  +  X                                     -1
                                  XXXX  |  X
                                XXXXXX  |
                                    XX T|  X
                                     X  |T
                                        |
                                        |  X
   -2                                   +                                        -2
  <less> --------------------- PERSON  -+- ITEM    ----------------- <freq>
```

Figure 3: Wright Map, 32-Item Model

Reliability and validity

To measure test-retest reliability, the 32-item scale was administered to 82 students, recruited in face-to-face intercepts, resulting in 80 usable surveys. Seventy-three participants provided email addresses for a retest and were contacted approximately two weeks after they initially completed the scale. Thirty-six participants completed the retest. For the participants completing both scales, the mean score on the initial test was 3.10 (s.d. 0.54) and on the retest was 3.08 (s.d. 0.53). Test-retest reliability calculated using Pearson's product-moment correlation was 0.87 ($p<0.01$). In addition, for the 32-item measure, Cronbach's Alpha was 0.90, reflecting strong internal consistency in the scale.

Validity can be assessed in part by considering the fit statistics for the items and the overall model. Ideally the mean square for an item is 1.0, though a range of 0.5 to 1.5 is acceptable, and up to 2.0 can be retained without degrading the scale (Linacre, 2012b). Most outfit (sensitive to outliers) mean squares for items fell within the 0.5 to 1.5 range. One item was close to 2.0 (carrying a water bottle). The overall outfit mean square was 1.01.

DISCUSSION

The overall purpose of the current study was to develop a pro-environmental behavior scale for young adults. After several steps, which included pilot testing and collecting data using a draft scale, the Environmental Behavior Scale for Young Adults (EBS-YA), a 32-item Rasch scale, was created. Compared to adult measures, like the GEB, the final EBS-YA scale places more emphasis on waste avoidance (9 items), waste sorting or management (3 items), and small energy conservation steps (7 items) and less on home energy conservation and transportation. Other items related to active teaching/doing (5 items) and food (8 items).

The first aim of the study was to develop a pool of pro-environmental behaviors relevant to young adults, and to do so by studying "positive deviants." Approximately 100 behaviors were identified through interviews and focus groups with young adults who actively engage "above and beyond" in terms of pro-environmental behavior. Gathering data from positive deviants helped to ensure scale development began with a comprehensive pool of behaviors that accurately represented pro-environmental behaviors engaged in by young adults who have some control over their environment but do not own a home and may not own a car. Many items, such as turning off lights and recycling, were consistent with items commonly identified other pro-environmental behavior scales. Other items, including buying food directly from farmers and avoiding single-use products, were different and might be a reflection of young adults' capabilities (compared to buying energy efficient appliances, for example) and of contemporary environmental interests. In-depth discussions with positive deviants also allowed for questions to be written very specifically in terms of context and the behaviors themselves. Where relevant, the items refer to a specific place (e.g., home, school).

The second aim of the study was to create a valid, reliable scale. Reliability refers to the precision and the consistency of an instrument (Kerlinger & Lee, 2000). (For example, if a person steps on a bathroom scale several times in succession, we would expect the scale to report the same weight each time. To the extent that it does not produce the same result, we know we have some error in the measure.) One way to assess reliability is to administer a scale to the same individuals twice (i.e., test-retest reliability). Test-retest reliability calculated using the Pearson Product Moment Correlation Coefficient for EBS-YA was 0.87, which indicates quite consistent answers by participants between their first and second tests. Test-retest is a suitable reliability measure for the scale because the construct involves regular or routine behaviors (i.e., the construct would be expected to be relatively stable, rather than something that varies considerably day-to-day). Another aspect of reliability is internal consistency, which concerns how correlated items within a scale are with one another and can be measured using Cronbach Alpha (for interval scales; or Kuder Richardson for dichotomous scales). For EBS-YA, Cronbach's Alpha was 0.90, indicating strong internal consistency of the measure. Reliability is a necessary, but not sufficient condition for validity.

Validity refers to how well an instrument actually represents the construct in question (Kerlinger & Lee, 2000). Multiple steps were taken to build and to evaluate the face validity of the scale. The development of an item pool using highly knowledgeable participants helped to ensure that the items were both relevant to and representative of young adults' pro-environmental behavior. Pilot testing and random probes explored participants' comprehension of the items and led to further wording refinements and response option alterations. With the Rasch model, construct validity was also evaluated in terms of item order. Item order was consistent with expectations regarding item difficulty, based in part on conversations with positive deviants. Finally, the scale was also assessed in terms of fit statistics, which can be used to help determine whether an instrument is measuring a single underlying construct (Boone, 2016). All but one item fell within the desirable range, with the remaining item still within a range that is acceptable.

Limitations

Threats to external validity

Data were collected from students at a single university in the northeastern United States, so there is a selection threat to external validity. The scale might have limited generalizability to other populations. One factor that might make the results from this particular university more generalizable than if the study had been conducted at another university is that a majority of students live in off-campus housing (i.e., not dorms), so there is some variability in the living arrangements participants experience.

Threats to internal validity

While the measure is framed in terms of age, it is possible that some of the behavioral distinctions explored in the study are due to participants' living arrangements rather than age per se, specifically dorm living. However, as noted above, a large percentage of students at this university live off campus in living arrangements similar to many young adults' living arrangements. In one pilot test (n=169), students were asked whether they lived in a dorm or another type of living quarters. Forty percent lived in a dorm. A comparison of the two groups' mean scores on the pilot measure (dorm, $\bar{x}$=3.06, s.d.=.43; other living quarters, $\bar{x}$=2.92, s.d.=.55) showed no significant difference (t=1.68; p=.10).

Threats to construct validity

The scale described in this study is subject to several threats to construct validity. First, all of the data collected relied on self-report of behaviors. Second, participants may have been effected by evaluation apprehension, if they thought that certain answers were more socially desirable than others. Overall, the development of a scale involves a certain amount of judgment regarding what items to remove and what items to retain. Another researcher might have made different choices. However, the development of an item pool and multiple scale development steps were thorough and the result would likely not be extremely different.

Future Research

Steps can be taken to further validate the scale. For example, to further assess construct validity, future research might compare observations, reports by others (e.g., roommates), or direct measurements (e.g., utility bills) with self-reported responses to the measure. Also to assess construct validity, the measure could be administered to known groups (e.g., members of an active environmental organization and members of a group opposing environmental policies), and the results from the two groups compared. To strengthen external validity, additional data could be collected from samples from different populations (e.g., young adults who are not students, students at other colleges and universities).

In terms of research to inform our understanding of pro-environmental behavior in young adulthood, across the lifespan, and in response to sustainability programs, there are a number of avenues for future research. In the short to medium term, the scale can be used to measure young adults' behavior before and after a pro-environmental intervention. For example, the scale could be administered to incoming freshman at a college and then again in subsequent years or upon graduation. Comparing students' pre and post responses would provide valuable information regarding the effectiveness of sustainability awareness and education programs. The scale could also be used to compare populations of young adults (e.g., young adults in different geographic regions, attending different types of schools, etc.).

In the long-term, the scale could be used as a foundation for longitudinal research. The scale could be administered to individuals at a young age, and then later those same individuals could be asked to complete a different scale aimed at older adults (such as the GEB). Findings could provide insight into whether young adult pro-environmental behavior predicts more impactful behaviors later in life.

Finally, there are two trends that indicate the scale might continue to be useful in later adulthood because it is tailored toward people who have less control over their environments.[10] First, car ownership is becoming less important in the U.S. The percent of young people who have a driver's license is in decline (Sivak & Schoettle, 2016). Second, with continued urbanization and rising housing costs, people are exploring new forms of co-living that include small private spaces and shared living areas (see Robinson, 2017; Widdicombe, 2016).

[10] Researchers using the scale outside of a university environment would need to modify instructions slightly (i.e., remove "school") and substitute "work" for "campus."

Until now, pro-environmental behavior scales primarily focused on the behavior of either young children, or well-established or older adults (who often own a home and a car). With its focus on behavior relevant to young, semi-independent adults, EBS-YA fills an important gap in the literature. Given ongoing population growth and environmental pressures, as well as continued growth in urban areas and emerging lifestyle trends among young adults, the scale should be a valuable research tool for some time. EBS-YA can be used immediately to benchmark environmental activity among young adults and to measure the impact of behavior change interventions. The scale also promises to be useful for long-term research on environmental behavior over the lifespan.

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APPENDIX

Table A1: Pilot Testing Item Pool

1. For short trips, I choose walking or biking over other methods of transportation
2. I choose the stairs rather than the elevator
3. For long trips that involve a car, I choose to carpool rather than drive alone
4. For short trips, I drive alone
5. For short trips, I choose to carpool or to take a bus over driving alone
6. When I choose where to live, I factor in being able to walk, bike, or take public transportation to school (or work) rather than drive
7. When I drive a car, it is efficient (gets good gas mileage)
8. I regularly maintain my car, such as keeping tires inflated properly and having it serviced at regular intervals
9. When driving, I combine errands
10. I do everything I can to choose the most efficient form of transportation
11. I recycle where I live
12. I recycle on campus
13. I compost where I live
14. I compost on campus
15. I go out of my way to recycle
16. I go out of my way to compost
17. When I walk past litter, I pick it up
18. I choose products with minimal packaging
19. When I buy a product with packaging, I choose one with recyclable (or compostable) packaging
20. I choose to make my own toiletries, like lotion
21. I choose to make my own cleaning products
22. I avoid disposable or single-use products
23. I choose biodegradable products
24. I choose recyclable products
25. I minimize the amount of stuff I buy
26. I choose products made with natural ingredients
27. I choose cleaning products made with natural ingredients
28. I take steps to make my things last longer
29. When I buy a product, I choose the most durable one
30. I avoid buying products that won’t last long

31. In my daily life, I use consumable products, like paper towels or sandwich bags
32. I reuse school or office supplies rather than purchase new
33. I take a reusable mug to school (or work)
34. I take a refillable water bottle to school (or work)
35. I take reusable utensils to school (or work)
36. I choose cloth napkins over paper
37. I reuse containers
38. I use reusable shopping bags
39. I choose to buy used clothes over new
40. I choose to buy used furniture over new
41. I choose to buy used products over new
42. When my clothes wear out, I repurpose them
43. I borrow rather than buy products that I don't use regularly
44. If I buy something with packaging, I reuse the packaging
45. I do everything I can to minimize the amount of waste I produce
46. When I buy food, I choose local foods
47. When I cook, I cook in batches
48. I eat meatless meals
49. I eat vegan meals
50. I do everything I can to avoid food waste
51. I use up leftovers
52. When I buy food for home, I plan with the goal of minimizing food waste
53. I get through the week without throwing out any food
54. I choose the least processed foods possible
55. I choose organic foods when available
56. I choose foods that have the least environmental impact
57. In my daily life, I buy take out food with throwaway packaging
58. When I choose fruits and vegetables, I choose in-season
59. I unplug electronics when they're fully charged
60. I do everything I can to minimize energy use
61. I use energy saving settings on electronics
62. I unplug small appliances when not in use
63. If I use a computer in a public or shared space (like a library), I will shut if off when I'm done
64. In shared spaces where I live (like the kitchen), I turn off the lights if I'm the last person to leave the room

65. In private spaces where I live (like my bedroom), I turn off the lights when I leave the room
66. In public spaces, such as a bathroom or classroom, I turn off the lights if I'm the last person to leave
67. Where I live, I use daylight rather than turn on lights when possible
68. In public spaces, such as a shared office or classroom, I will make adjustments to use daylight (such as raise shades and turn off lights)
69. I limit the amount I print
70. If I need to print, I will print double sided
71. I minimize my use of electronics
72. Where I live, I keep the heat setting as low as comfortably possible
73. On campus, I will turn down the heat in shared spaces
74. Where I live, I take steps to minimize the need for heat, such as installing insulated curtains or weatherstripping
75. When I leave home, I turn the heat down (manually or using a programmable thermostat)
76. When I brush my teeth, I keep the water running
77. When I shower, I limit my time to a few minutes or less
78. I shower every day
79. When I shower, I turn off the water when lathering up
80. I wait to wash clothes until I have a full load
81. For short trips that involve a car, I choose to carpool rather than drive alone
82. I wear clothing multiple times before washing
83. When I wash clothes, I use cold water
84. I wait to run the dishwasher until it is full
85. I do everything I can to conserve water
86. I air dry my clothes rather than use a clothes dryer
87. I teach others specific behaviors to reduce their environmental impact
88. I help others recycle or compost correctly
89. I teach others about environmental issues
90. I actively work to change policy to protect the environment (government, school, or other organizational policy)
91. I inform myself on environmental issues for personal reasons (not for school or work)
92. I do everything I can to be informed about environmental issues
93. I make changes to my surroundings to make it easier for me to behave more sustainably
94. I actively work to preserve nature or natural spaces
95. I buy food directly from farms (through a farm share or at a farmers' market)
96. For long trips, I drive alone

97. For long trips, I fly
98. For long trips, I carpool
99. For long trips, I take a bus or train

TABLE A2: REVISED TESTING ITEM POOL

1. I reuse containers
2. For short trips, I choose walking or biking over other methods of transportation
3. If I use a computer in a public or shared space (like a library), I will shut if off when I’m done
4. If I buy something with packaging, I reuse the packaging
5. In shared spaces where I live (like the kitchen), I turn off the lights if I'm the last person to leave the room
6. For long trips that involve a car, I choose to carpool rather than drive alone
7. I do everything I can to be informed about environmental issues
8. I actively work to preserve nature or natural spaces
9. I inform myself on environmental issues for personal reasons (not for school or work)
10. I go out of my way to compost
11. When I shower, I limit my time to few minutes or less
12. I choose foods that have the least environmental impact
13. For short trips that involve a car, I choose to carpool rather than drive alone
14. I teach others about environmental issues
15. I actively work to change policy to protect the environment (government, school, or other organizational policy)
16. When I drive a car, it is efficient (gets good gas mileage)
17. I choose to buy used clothes over new
18. I do everything I can to avoid food waste
19. I choose cleaning products made with natural ingredients
20. I buy food directly from farms (through a farm share or at a farmers’ market)
21. I choose products with minimal packaging
22. I minimize my use of electronics
23. I unplug electronics when they’re fully charged
24. When I buy food, I choose local foods
25. I help others recycle or compost correctly
26. I avoid disposable or single-use products
27. I do everything I can to minimize the amount of waste I produce
28. When I choose where to live, I factor in being able to walk, bike, or take public transportation to school (or work) rather than drive
29. For short trips, I choose to carpool or to take a bus over driving alone
30. I limit the amount I print
31. I do everything I can to choose the most efficient form of transportation

32. When I cook, I cook in batches
33. I choose biodegradable products
34. I recycle where I live
35. When I buy a product with packaging, I choose one with recyclable (or compostable) packaging
36. I eat meatless meals
37. I take steps to make my things last longer
38. I compost where I live
39. I use energy saving settings on electronics
40. I choose recyclable products
41. I choose products made with natural ingredients
42. I eat vegan meals
43. In public spaces, such as a bathroom or classroom, I turn off the lights if I'm the last person to leave
44. When I choose fruits and vegetables, I choose in-season
45. When I walk past litter, I pick it up
46. In private spaces where I live (like my bedroom), I turn off the lights when I leave the room
47. Where I live, I keep the heat setting as low as comfortably possible
48. I unplug small appliances when not in use
49. I recycle on campus
50. For long trips, I fly
51. I take a reusable mug to school
52. I choose the least processed foods possible
53. I take a refillable water bottle to school
54. I do everything I can to conserve water
55. When I buy food for home, I plan with the goal of minimizing food waste
56. Where I live, I take steps to minimize the need for heat, such as installing insulated curtains or weatherstripping
57. Where I live, I use daylight rather than turn on lights when possible
58. I choose organic foods when available
59. I get through the week without throwing out any food
60. I teach others specific behaviors to reduce their environmental impact
61. I reuse school or office supplies rather than purchase new
62. I make changes to my surroundings to make it easier for me to behave more sustainably
63. I compost on campus
64. I take reusable utensils to school
65. When my clothes wear out, I repurpose them
66. I avoid buying products that won't last long

67. I use reusable shopping bags
68. I do everything I can to minimize energy use
69. I go out of my way to recycle
70. I borrow rather than buy products that I don’t use regularly
71. I use up leftovers

Table A3: Rasch Model Testing Item Pool

1. I actively work to preserve nature or natural spaces
2. I inform myself on environmental issues for personal reasons (not for school or work)
3. I teach others about environmental issues
4. I actively work to change policy to protect the environment (government, school, or other organizational policy)
5. I help others recycle or compost correctly
6. I teach others specific behaviors to reduce their environmental impact
7. In shared spaces where I live (like the kitchen), I turn off the lights if I'm the last person to leave the room
8. I minimize my use of electronics
9. I unplug electronics when they're fully charged
10. I use energy saving settings on electronics
11. In public spaces, such as a bathroom or classroom, I turn off the lights if I'm the last person to leave
12. In private spaces where I live (like my bedroom), I turn off the lights when I leave the room
13. I unplug small appliances when not in use
14. Where I live, I use daylight rather than turn on lights when possible
15. I do everything I can to minimize energy use
16. I choose foods that have the least environmental impact
17. I buy food directly from farms (through a farm share or at a farmers' market)
18. When I buy food, I choose local foods
19. I eat meatless meals
20. I compost where I live
21. I eat vegan meals
22. When I choose fruits and vegetables, I choose in-season
23. I choose the least processed foods possible
24. When I buy food for home, I plan with the goal of minimizing food waste
25. I choose organic foods when available
26. I get through the week without throwing out any food
27. I use up leftovers
28. For short trips, I choose walking or biking over other methods of transportation
29. For long trips, I fly
30. I reuse containers

31. If I buy something with packaging, I reuse the packaging
32. I choose to buy used clothes over new
33. I choose products with minimal packaging
34. I avoid disposable or single-use products
35. I limit the amount I print
36. I choose biodegradable products
37. When I buy a product with packaging, I choose one with recyclable (or compostable) packaging
38. I take steps to make my things last longer
39. I choose recyclable products
40. I choose products made with natural ingredients
41. I take a reusable mug to school
42. I take a refillable water bottle to school
43. I reuse school or office supplies rather than purchase new
44. I take reusable utensils to school
45. When my clothes wear out, I repurpose them
46. I avoid buying products that won't last long
47. I use reusable shopping bags
48. I borrow rather than buy products that I don't use regularly
49. I go out of my way to compost
50. I recycle where I live
51. When I walk past litter, I pick it up
52. I recycle on campus
53. I compost on campus
54. I go out of my way to recycle
55. When I shower, I limit my time to a few minutes or less

TABLE A4: FINAL INSTRUMENT

We each have different habits. Think about what you **typically do while living at school** (your school "home"). As you read each of the following statements, **consider how consistent your behavior is with the statement**, and then choose the appropriate response, from **Never to Always**.

	Never	Infrequently	Sometimes	Often	Always
When I buy food, I choose local foods.					
In public spaces, such as a bathroom or classroom, I turn off the lights if I'm the last person to leave.					
I teach others specific behaviors to reduce their environmental impact.					
I choose organic foods when available.					
I borrow rather than buy products that I don't use regularly.					
I compost on campus.					
I choose biodegradable products.					
I use energy-saving settings on electronics.					
I unplug small appliances when not in use.					
I inform myself on environmental issues for personal reasons (aside from school or work).					
I actively work to preserve nature or natural spaces.					
In shared spaces where I live (like the kitchen), I turn off the lights if I'm the last person to leave the room.					
I eat vegan meals.					
I avoid disposable or single-use products.					
I choose products with minimal packaging.					
I eat meatless meals.					
When I buy food for home, I plan with the goal of minimizing food waste.					
I recycle on campus.					
I use up leftovers.					
I choose recyclable products.					

	Never	Infrequently	Sometimes	Often	Always
I recycle where I live.					
I actively work to change policy to protect the environment (government, school, or other organizational policy).					
I take a refillable water bottle to school.					
I reuse school or office supplies rather than purchase new.					
I minimize my use of electronics.					
Where I live, I use daylight rather than turn on lights when possible.					
When I choose fruits and vegetables, I choose in-season.					
I buy food directly from farms (through a farm share or at a farmers' market).					
I help others recycle or compost correctly.					
I use reusable shopping bags.					
I reuse containers.					
In private spaces where I live (like my bedroom), I turn off the lights when I leave the room.					

Year in school:
Fr
So
Jr
Sr
Grad

Gender: _______________________

CHAPTER 5

CONCLUSION

Finding solutions to environmental problems is imperative for human health and for the health of our natural environment. Human behavior, particularly how we use and dispose of products, is one important factor driving environmental problems (Hertwich, 2005). To reduce environmental impacts, it is important to understand what shapes behavior, take behavior into account when designing products and other aspects of the built environment, and develop effective behavior change interventions.

Environmental psychology offers an interdisciplinary approach to understanding behavior and what influences it, especially contextual factors including the natural and built environments. The bio-ecological model in particular, offers a useful framework for seeing how different factors might influence behavior and for designing interventions that leverage inter-related facets of a system to support behavior change.

For example, if we were to consider a person's behavior relative to physical activity, the model could be used to map a range of factors that might influence whether a person walks for exercise (see Figure 1). At the center of the model are an individual's person's personal attitudes, beliefs, current health, and so on. Here we might look at factors such as a person's attitudes toward exercise, beliefs about walking as an effective form of exercise, and ability to begin a walking routine. Next, we could look at the microsystems that shape a person's behavior. For example, social factors at the microsystem level might include a person's family, peers, and co-workers, and those people's beliefs and norms about exercise and walking. For the physical environment at the microsystem level, factors might include whether a person's neighborhood has sidewalks or whether they have access to supports like comfortable walking shoes or a step-tracking app. A mesosystem factor might be whether there are safe walking routes between home and work. We can continue on to look at the exosystem, and examine factors like public health education regarding exercise, media messages about walking as a form of exercise, and even the likelihood that a person in a given community could be the victim of a crime while walking. Finally, we might consider macrosystem factors such as societal-level culture, customs, and values regarding exercise.

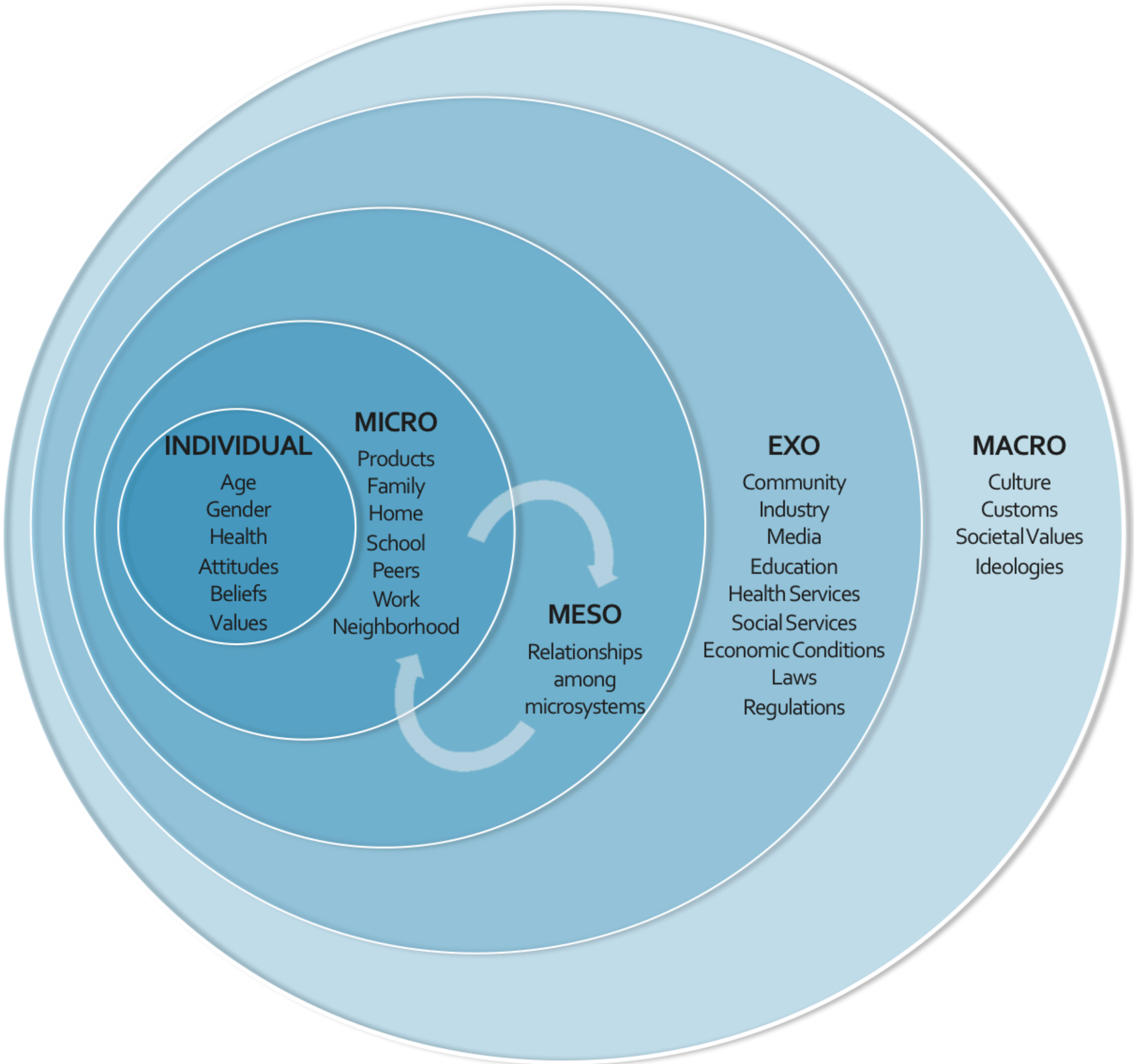

Figure 1: The Bio-Ecological Model

In the field of public health, there has been a shift away from the individual level toward the use of multi-level interventions that not only target personal knowledge, beliefs, and attitudes, but also acknowledge the powerful influence the environment has on behavior and on health outcomes (French, Story, & Jeffery, 2001; McLeroy, Bibeau, Steckler, & Glanz, 1988; Razani & Tester, 2010; Sallis, 1998; Stokols, 1992; Story, Kaphingst, Robinson-O'Brien, & Glanz, 2008; Wells, Ashdown, Davies, Cowett, & Yang, 2007; Wells, Evans, & Yang, 2010) (See Figure 2). So, in the example above, an intervention might include a public awareness campaign targeted at certain individuals in a community, but might also include the construction of sidewalks to furnish those individuals with an environment that supports walking and the installation of lights to prevent crime. (For an example of a multi-level intervention to promote physical activity that included changes to the physical environment, see Kerr et al., 2018).

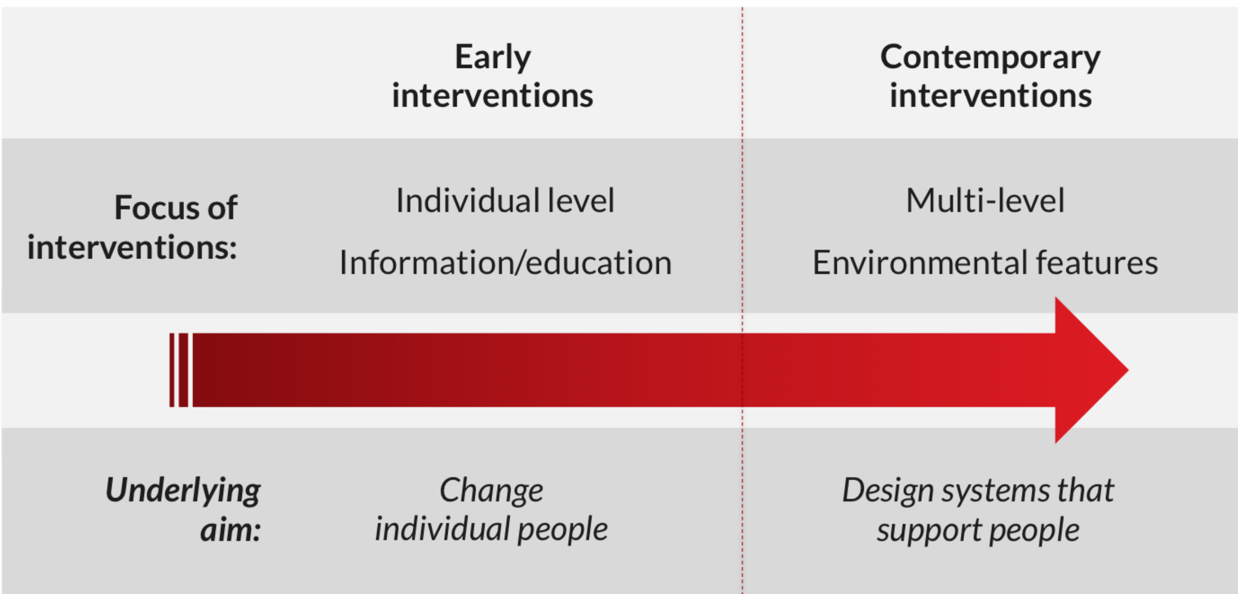

Figure 2: Shift in public health toward the use of systems-based, multi-level interventions

Research on and interventions for environmentally sustainable behavior have shifted somewhat away from a focus on the individual toward a broader, systems view. There is, for example, recognition that control over one's environment is an important factor influencing pro-environmental behavior, and that the removal of barriers can be an effective behavior change intervention 10/9/2018 8:09:00 PM. The emphasis is still very much on individual attitudes, beliefs, knowledge, personal norms, and motivation, though (Bamberg & Möser, 2007; Clayton et al., 2015; Maki & Rothman, 2017).

As environmental problems worsen, a renewed approach to supporting environmentally sustainable behavior is needed. Recycling, which is a frequent focus of behavior change efforts, has stagnated in the United States (U.S. Environmental Protection Agency, 2015). The most heralded energy conservation interventions achieve modest gains. (A highly cited norms-based intervention involving hundreds of thousands of homes resulted in a 2% decrease in energy consumption; Allcott, 2011.) Today, the effort needed to combat global climate change is enormous, and touches on most all human behavior, from eating to energy use. Overall, 40 years of pro-environmental behavior interventions focusing on individual attributes have had an impact, but not at the scale we need (Schultz, 2014).

Efforts to support environmentally sustainable behavior could benefit by more explicitly and intentionally using a systems view with multi-level interventions. Figure 3 provides an example based on water conservation behavior relative to watering lawns. Again, we can identify a range of influences on a person's behavior, from individual knowledge about water conservation technologies available to societal values regarding well-manicured lawns. A multi-level intervention in one community might seek to raise residents' understanding of the water conservation steps they can take, to alter local norms regarding lawns, and change a local water ordinance. The bio-ecological model can be used to map factors, identify potential leverage points for an intervention, and design an intervention that addresses multiple levels of influence.

The model can be similarly useful in facilitating inter-disciplinary work. Cognitive psychologists might see opportunities at the individual level, sociologists might pursue a better understanding of norms, and political scientists might test different policy models. Typically, such efforts are undertaken in parallel, separately. The model can be a tool to help researchers and others collaborate on more powerful multi-level interventions with the benefit of insight from different perspectives and an improved understanding of the interdependencies among factors at different levels.

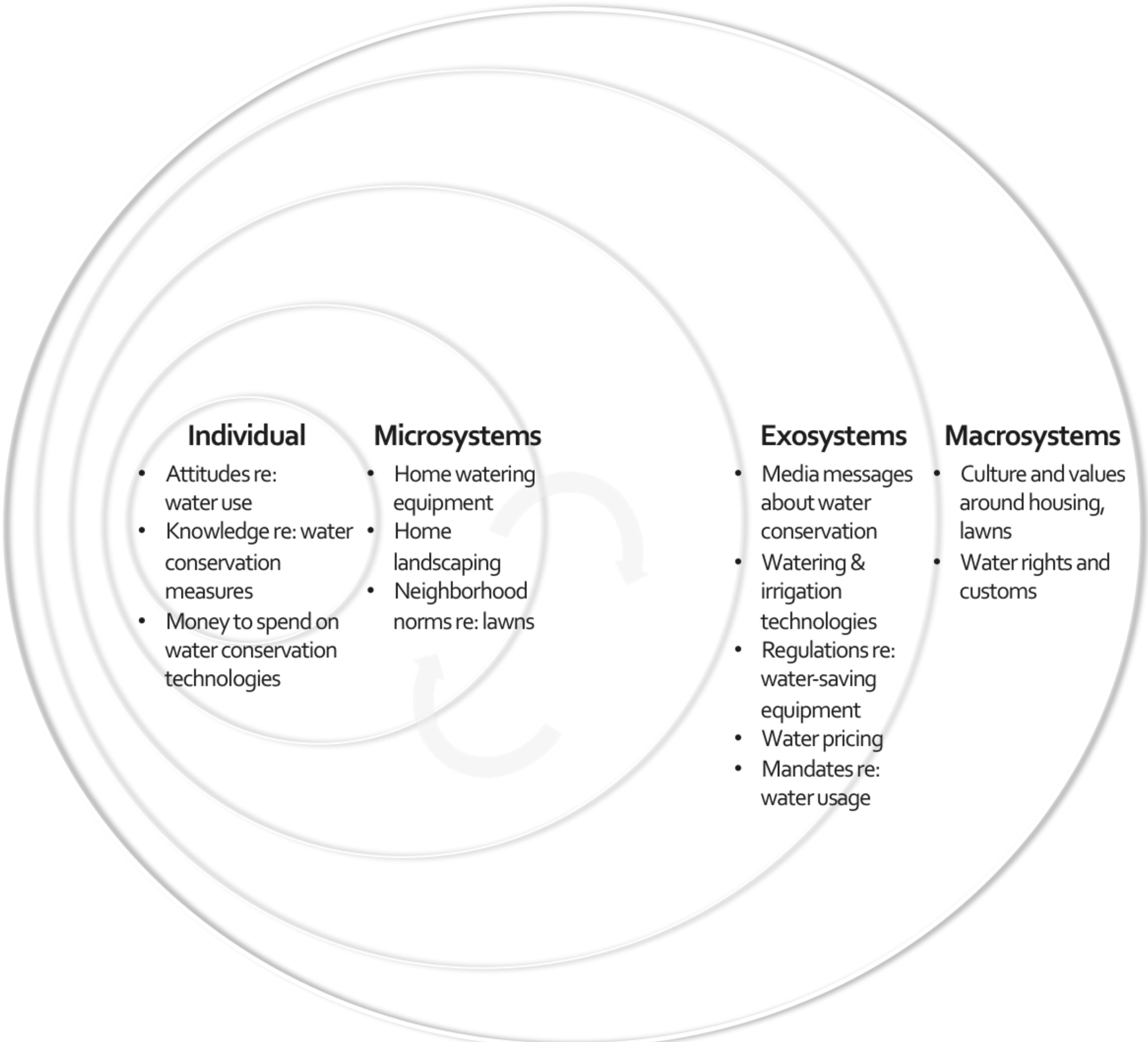

Figure 3: Systems View of Factors Influencing Water Conservation Behavior

Finally, the model can be used to highlight the role of the built environment, from products, to buildings, neighborhoods, cities, and more. The design of the built environment shapes our behavior in myriad ways. Research and interventions to support sustainable behavior would benefit from considering how products and systems are designed, and whether and how designs take behavior and issues like convenience and ease of use into account. There is enormous potential to "build in" behavior through design. One intention of the three studies presented in this dissertation was to address the physical context for behavior (whether the design of something like a fume hood or the specific location where a pro-environmental behavior takes place), and, where appropriate to consider people's interactions with the built environment relative to the product lifecycle (i.e., to consider behavior associated with the product use-phase and end-of-life). With an increasingly complex world and humans' limited decision making and cognitive processing abilities, designing an environment that supports environmentally sustainable behaviors could be a very beneficial strategy.

The three studies presented in this dissertation explored behavior, its precursors, and its impacts during two phases of a product's lifecycle – the use phase and end-of-life – and considered the importance of context for pro-environmental behavior. The studies considered both deliberative and routine or habitual behaviors. The studies also incorporated a range of methods, including experimentation, cross-sectional surveys, and the development of a measurement instrument. This final chapter provides a brief summary of each of the studies, an overview their collective strengths, and a discussion of implications for future research.

Studies

Chapter 2: Creating a New Behavior to Address a New Problem: The Case of Safe Drug Disposal

Chapter 2 addressed drug disposal, an issue that directly impacts both human health and the health of our natural environment. The aim of the three Chapter 2 studies was to obtain an accurate estimate of the disposal methods being used in a general population, to describe people who participated in a formal disposal program (a take-back event), and to test whether disposal method choice might be influenced by how the problem was presented (as an environmental versus a public health issue).

Findings show that the disposal of leftover drugs is common. More than 80 percent of a random sample of New York State residents reported that they had disposed of a medication in the past. Approximately 70 percent disposed of leftover medications at home, primarily via trash or flushing. Convenience was the most important factor for participants' drug disposal choice overall, though those who cited environmental factors were more likely to choose an out-of-home disposal method, such as a take-back program. Take-back event participants were older, more likely to be female, more educated, and wealthier in comparison to local, state, and national populations. Event participants showed preference for a drop-off program at a pharmacy during regular business hours over a public event. Event participants also expressed strong agreement for both environmental and public health concerns relative to drug disposal. Most experimental survey participants had disposed of a medication in the past, and had done so in patterns similar to New York State residents (i.e., about 70 percent via trash or flushing and the remainder out-of-home). Results from the experimental survey indicate that presenting drug disposal as a public health versus an environmental issue had no effect on participants' preferences or intention to use various disposal methods.

While there were limitations in each of the three drug disposal studies, together they represent one of the broadest inquiries into individual drug disposal behavior to date, and, to the best of our knowledge, include the most rigorous estimates of the prevalence of individual drug disposal and people's choice of drug disposal methods. Drug disposal has recently become a prominent issue of concern, particularly with the rise of addiction and overdose deaths (Christie et al., 2017). There is widespread desire to get drugs out of homes as a prevention measure. States and smaller municipalities are instituting take-back programs supported with public dollars and by the pharmaceutical industry. However, where such programs have been available, participation is relatively low (Egan, Gregory, Sparks, & Wolfson, 2016).

Drug storage and disposal need more investigation to and experimentation with strategies that might work to safely remove leftover drugs from homes. As the issue matures, we also need a holistic strategy that considers source reduction (i.e., how to prevent leftover drugs from occurring in the first place). This might include research on behaviors throughout the chain – prescribers (doctors and nurse practitioners, dentists, veterinarians), patients, pharmacies, and pharmaceutical companies (see for example Compton, Boyle, & Wargo, 2015). Behavior also needs to be a consideration when designing new medication dispending and disposal innovations. For example, Pill Pack, recently acquired by Amazon, is a prescription drug service that combines a person's doses for multiple medications into individual daily pouches to increase adherence, an important issue in health behavior. But such a design has implications for disposal behavior (e.g., what does a person do one week into a month's supply when one or more of the medications needs to be changed, but the others do not?) and packaging waste (i.e., plastic film that is difficult to recycle). Also, in-home disposal pouches designed to neutralize dangerous medications require resources for materials and production and then contribute to plastic waste, all of which ultimately harms natural and human health. Overall, any solution needs to designed with a systems perspective that takes behavior into account and considers the possibilities for unintended environmental and health impacts.

Chapter 3: Lab Fume Hood Closure: A Behavior Change Experiment

Chapter 3 focused more narrowly on how people interact with a product and how we might influence their use of that product to result in fewer environmental impacts. Specifically, Chapter 3 considered the frequent failure of lab workers to close the door, or “sash,” on fume hoods, which has outsized implications for energy use and poses an immediate safety risk. The aim of Chapter 3 was to test whether a simple, low-cost intervention that included a signifier and comparative feedback would increase fume hood closure behavior in science laboratories. The signifier, a sticker that was cut in half and placed partly on the glass sash and partly on the hood frame, alone did not have a significant effect on closure behavior. The combination of the sticker and comparative feedback, which displayed closure activity for each hood, did result in significantly fewer instances of hoods being left open in both occupied and unoccupied states. In the occupied state, one year after the stickers were installed, hood closure behavior was still improved relative to the baseline period.

The experiment was limited, but is the only fume hood closure study to date to include an experiment with a control group and with automated building system data with occupancy status. The widespread adoption of automated building systems and "smart building" technologies present new opportunities for studying behavior and behavior change in the built environment and to incorporate measures that do not rely on self-report (Hong, Taylor-Lange, D’Oca, Yan, &

Corgnati, 2016; Hong, Yan, D'Oca, & Chen, 2017). Sensors that detect occupancy status, estimate the number of persons in a room, track equipment usage, and record occupants' interaction with heating, cooling, and lighting systems can all provide sources of information on behavior. Automated building data can be used comparatively (e.g, to better understand why energy usage is higher in one area or another), to identify problem areas and develop interventions, and then to test the impact of interventions on behavior. However, during the building design process, there must be more consideration of occupant behavior and tools for measuring it. For the lab fume hood experiment, it took several months of investigation and consultation to program a method for extracting data from the building management system.

Chapter 4: Development of the Environmental Behavior Scale for Young Adults (EBS-YA)

Finally, Chapter 4 focused on young adults' pro-environmental behavior in context. The aims of Chapter 4 were to develop a pool of pro-environmental behaviors, including those engaged in by "positive deviants" and then to create a valid, reliable scale to measure pro-environmental behavior that is relevant to young adults and accounts for physical context. The pool of behaviors was developed in part through interviews and focus groups with university students who were non-homeowners between the ages of 18 and 25 and who actively participated in pro-environmental behaviors "above and beyond the norm." Initial conversations resulted in a list of 105 behaviors, which was subsequently narrowed through pilot testing, comparison of responses among the top and bottom quartile of respondents, additional testing, and eventually the creation and refinement of a Rasch model. The final instrument contains 32 items that address waste avoidance, waste sorting or management, small energy conservation steps, active teaching of others or policy action, and food.

The study was limited most notably by the dependence on a population from a single university and the use of convenience samples within that university. However, the overall approach, including conversations with positive deviants and testing with groups drawn from a general student population, revealed specific behaviors that were most relevant to young adults and enabled differentiation of behaviors by place when appropriate. While many other scales for older adults are tested in a university setting with students living in different circumstances (see for example Abraham et al., 2015), this scale was tested with samples more closely aligned with its intended uses. EBS-YA is most appropriate for use in university settings, where it might be useful to measure behaviors at different points in time (e.g., freshman and senior years, or before and after an intervention). The scale could be strengthened through testing and refinement using different samples (e.g., young adults who have not attended college, participants from different regions, backgrounds, etc.).

Collective Strengths

The studies presented in this dissertation present a fresh perspective on environmental behavior in context. Human behavior is complex and influenced by a multitude of factors. Behavior change interventions that work in one setting often fail to work in another. In the case of pro-environmental behavior, we still have much to learn about what works for what behavior in what setting (Schultz, 2014). What we do know is that context is an important factor: “One of the basic lessons from 60+ years of research in environmental psychology is that context matters. In many instances, context can override personal variables like attitudes or beliefs” (Schultz, 2014, pg. 113). A systems model that incorporates consideration of the physical environment, such as the one used here, provides a useful framework for studying varied influences on pro-environmental behavior. Likewise, a product lifecycle model is a useful tool for identifying and studying different behaviors carried out during different phases of a product's life, all of which have important implications for resource use. One of the strengths of the dissertation studies collectively was that the two models (systems and lifecycle) were brought together to consider how we might study and ultimately alter behavior for the health of our environment and human health.

Another strength of the dissertation was the wide range of methodological approaches used. The dissertation included cross-sectional studies, an experiment, and the creation of a measure. Specific methods included interviewing, focus groups, survey work, field work, and model development. Two of the dissertation studies incorporated observed behavior, in addition to self-reported behavior. The pharmaceutical disposal study intercepted people who were participating in a drug take-back event. The lab fume hood experiment was done in a natural setting and relied on data reported from an automated building system. The third study, the measurement scale, relied on self-report, but the pool of items was developed through in-depth discussions with persons known by others to be actively engaged in pro-environmental behaviors or part of a group actively working on environmental issues. Overall the combination of approaches and methods provides for a rich examination of pro-environmental behavior.

Future Research Directions

As the dissertation studies suggest, there are opportunities to study human behavior at two important phases of the product lifecycle: the use phase and end-of-life. A large portion of resource use associated with the products and the built environment occurs during the use phase (see for example Laitala & Boks, 2012). Therefore, changing the way people use buildings, consumer products, cars, clothing, and other aspects of the built environment can have a large impact on resource use. Similarly, closing the loop on consumption, such that resources are recovered for continued use or at least for low-impact disposal, can have a significant impact on human and environmental health.

Design for Sustainable Behavior

Design for sustainable behavior offers one potential approach for curbing resource consumption during a product's use phase. Design for sustainable behavior is a user-centered research framework that employs knowledge of how people use products to identify design solutions for shaping behaviors in environmentally sustainable ways (Boks, 2012; Selvefors, Pedersen, & Rahe, 2011). Changing behavior requires an in-depth understanding of how people interact with their environment, particularly with products. To date, design for sustainable behavior is primarily theoretical. Little empirical work has examined how alterations to design might influence use-phase consumption.

The fume hood experiment provides an example of how behavioral research can inform design for sustainable behavior. Findings from research on how people use existing products in the field can be considered during the design of new products to conserve energy or other resources. Behavioral experiments conducted with products that are in development could similarly inform design. Behavioral research can be extended to the built environment more generally (e.g., research about how we behave in buildings can be used to inform the building design process). For products where there is an interest in or incentive to reduce lifecycle impacts, or for building with performance goals [e.g., performance goals for a building's energy use, as specified in sustainable building programs like the Living Building Challenge (International Living Future Institute, 2018)], behavioral research can contribute to effective designs.

Behavior, Disposal, and Resource Recovery

Behavioral research can also contribute to improving resource recovery, which entails the return of products at the end of their useful life for recycling, repurposing, or extracting valuable materials, and to low-impact or safe disposal practices. Resource recovery is an important issue today for several reasons. First, the world is an essentially closed system with finite resources to support human well-being, while population and demands for resources are growing (United Nations, 2012). More efficient use of resources is an essential part of meeting the world's needs. Second, the value of many resources is growing. Waste is now recognized as an important resource and producers have an incentive to recover them (Perey, Benn, Agarwal, & Edwards, 2018). Third, in some cases, businesses are compelled by law to invest in product recovery and to meet performance targets (i.e., they must recover a certain amount of products) (Gupt & Sahay, 2015). Finally, there is an increased understanding today that improper disposal of materials can cause environmental harm and threaten human health (see for example Heacock et al., 2016).

With a growing understanding of the importance of resource recovery and proper disposal, in addition to pharmaceuticals, there are take-back programs in place for electronics, shoes, garments, paint, mattresses, and household hazardous waste, with more in development. Individual behavior is recognized as a crucial component in closed loop or circular systems, though relatively little research has been done to date, (Wastling, Charnley, & Moreno, 2018). Research could provide insight into the design of product recovery and disposal programs to attract more participation. For example, field experiments could test different program elements, disposal or take-back methods, and locations.

Conclusion

The dissertation presented here contributes to the study of pro-environmental behavior, as well as to the dialogue around design and behavior. For those concerned with pro-environmental behavior or the environmental impacts stemming from human behavior, the studies underscore the importance of considering the physical environment, the interactions between people and products or the built environment, people's behavior associated with different lifecycle stages of products, behavior as it relates to one's control over their environment, and the multi-layered systems that influence behavior.

Given our growing understanding the impacts of behavior on our environment, designers have a responsibility to consider how the design of products and the built environment influences human-environment relations, and then consequently what the implications are for environmental and public health. Through systems-based inquiry, environmental psychology can help to inform our understanding of human-environment relations and what we learn can be used to refine designs for better outcomes.

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